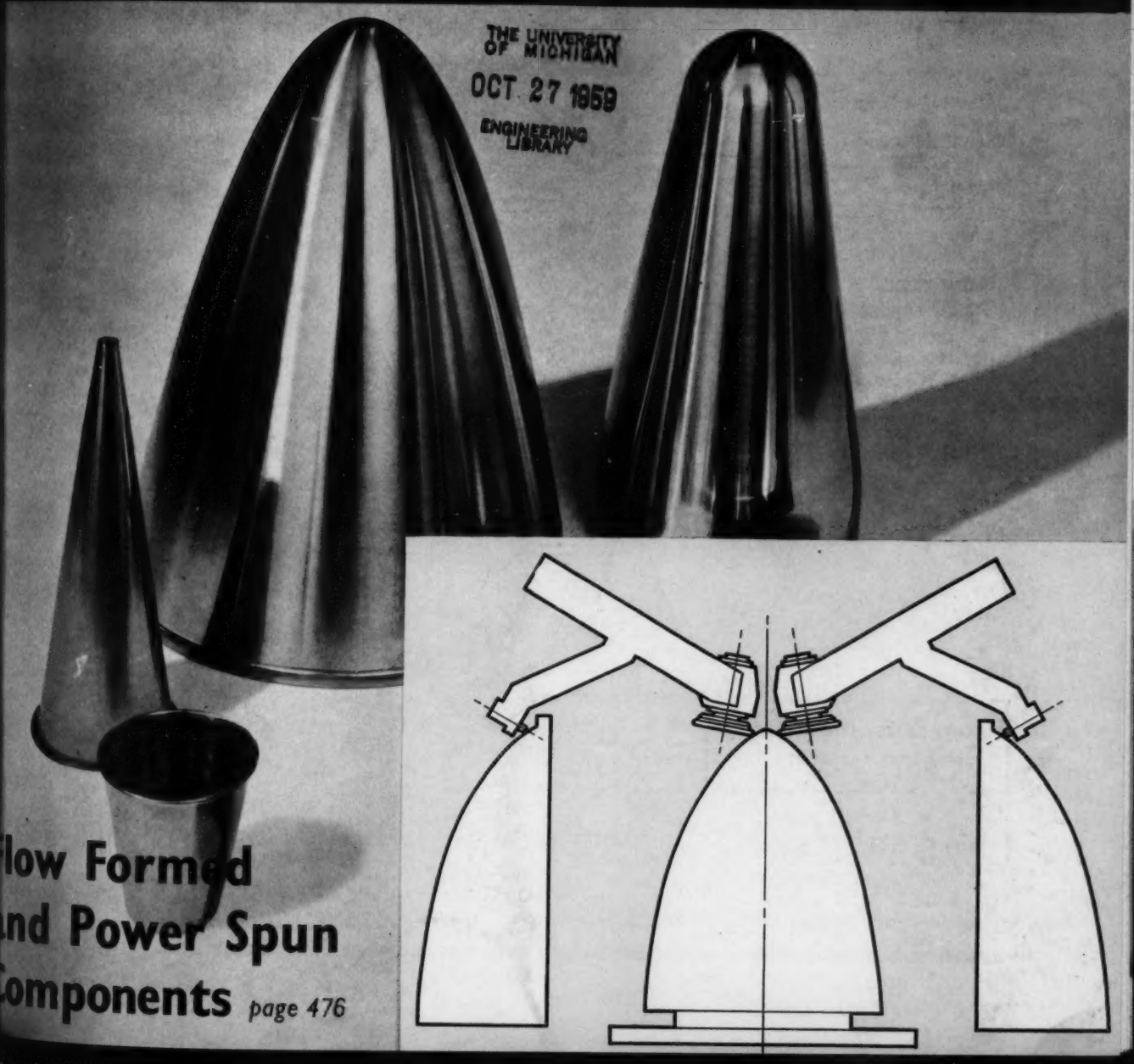
Engineering Materials and Design

THE UNIVERSITY OF MICHIGAN
OCT 27 1959
ENGINEERING LIBRARY



Flow Formed and Power Spun Components *page 476*

EMD 1429 for further information

A New Tool Steel

OSBORN

MUSHET SPECIAL 'V.G.'
– SPEED STEEL

Mushet Special "VG" high-speed steel is the very latest development of tool steels in the United Kingdom, by Samuel Osborn & Co., Limited. Remarkable results under production conditions are assured, far in advance of other tool steels in this category. Stocks of lathe tools, planer tools and toolholder bits, in this steel, are available in standard sizes.

IMPROVED PERFORMANCE FROM MACHINE TOOLS

If you use centre lathes, capstans, automatics, combinations, planers, shapers, boring mills, etc. these tools will:

- ★ **CUT FASTER**
- ★ **LAST LONGER**
- ★ **MACHINE TOUGHER MATERIALS** including Nimonic alloys
- ★ **REDUCE PRODUCTION COSTS**

● *ALSO AVAILABLE IN BAR AND BLANK FORM*

COMPREHENSIVE STOCKS CONSTANTLY MAINTAINED

SAMUEL OSBORN & CO., LIMITED

CLYDE STEEL WORKS, SHEFFIELD

FINE STEEL MAKERS · STEEL FOUNDERS ENGINEERS' TOOLMAKERS

Engineering Materials and Design

★ *The Magazine for Engineering Designers*

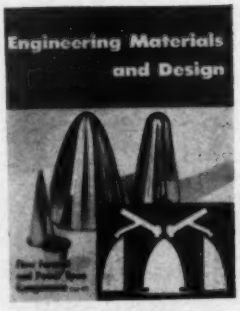
A HEYWOOD PUBLICATION

Vol. 2 No. 10 October 1959

EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
P. Burton



COVER — Typical component shapes produced by flow forming. Inset shows the basic principle of the process.

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square, Glasgow, Tel.: City 3492; 527 Madison Avenue, New York 22, N.Y., Tel.: Plaza 9-1171.

© Heywood & Company Ltd., 1959. Must not be reproduced without written permission.

ISSUE AT A GLANCE

page

FLOW FORMED AND POWER SPUN COMPONENTS 476
Two processes yet to be fully exploited in the U.K.

RUBBER AND EBONITE FOR LININGS AND COATINGS 486
Widening uses for abrasion and corrosion protection.

HIGH ALLOYS OF CHROMIUM, COBALT, COLUMBIUM, MOLYBDENUM AND VANADIUM 490
Maintaining specific mechanical properties at high temperatures.
By **H. R. Ogden.**

HOW TO CHOOSE MATERIALS FOR BEARING SURFACES 494
Minimising the effects of friction and wear in sliding parts.
By **P. G. Forrester**, M.Sc., F.I.M.

PRESENTATION OF GEAR DESIGN DATA 501
What the designer should know when specifying gear units.
By **R. Gardiner.**

OTHER FEATURES

First Engineering Materials and Design Exhibition 489
New Ideas in Design 483
Designer's Notebook 504
Hiduminium: Data Sheet 513
Stress Concentration Factors: Data Sheet 515
New Designs at the Farnborough Air Show 517
More Efficient Thermoelectric Materials 481

REGULAR FEATURES

Editorial 475
Materials in the News ... 469
Overseas Newsletter 507
New Books 510
New Materials and Components 519
News of Industry 527

Here are further Excellent Examples of ALZEN 305 Bearing Applications

ALZEN 305

Reg. Trade Mark B.752748

Alzen 305 is the White Bronze Bearing Alloy (British Pat. 725818) that reduces the weight of bearings by half, saves 40 per cent. of cost and lengthens bearing life.

It is supplied in the following forms: Ingot; Chill Cast Bars, cored and solid, in approx. 2 ft. lengths; Sand Castings; Shell Moulded Castings; Gravity Die Castings; Pressure Die Castings; Fully Machined Bushes and Bearings.

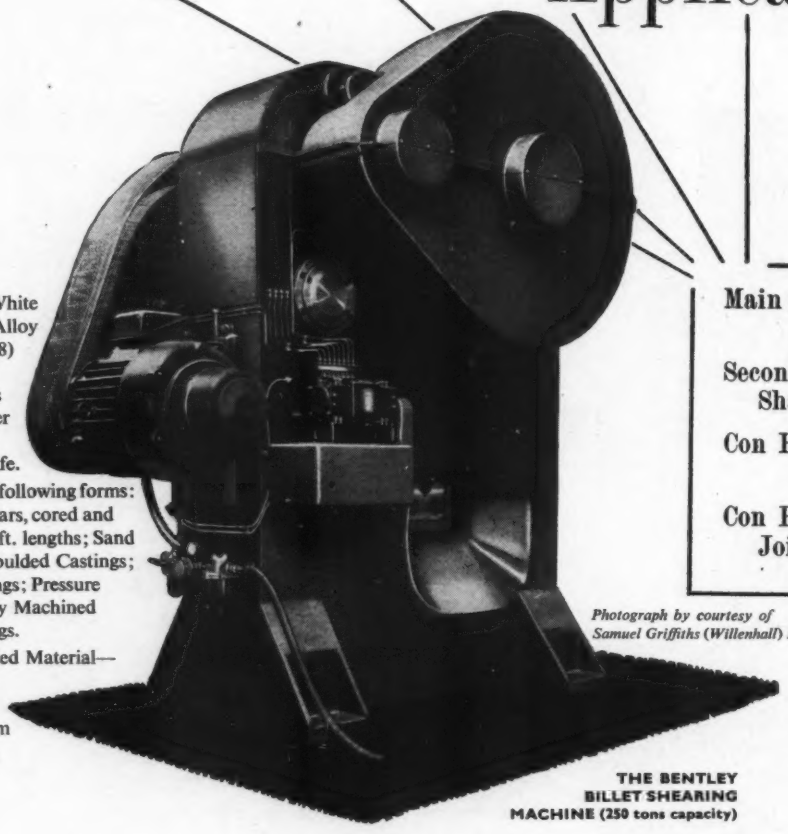
Also Alzen Extruded Material—specified as Alzen 305K Bar—Solid or Tube in random lengths of 10/12 ft.

Main Crank Shaft Bearings

Secondary Motion Shaft Bearings

Con Rod Big End Bearings

Con Rod Knuckle Joint Bearings



Photograph by courtesy of Samuel Griffiths (Willenhall) Ltd., Willenhall, Staffs.

THE BENTLEY BILLET SHEARING MACHINE (250 tons capacity)

May we send you technical data and samples for testing

HILL ALZEN (SALES) LTD., P.O. BOX 22, Stringes Lane, Willenhall, Staffs.

Telephone: WILLENHALL 227 (5 lines) Telegrams: Hill, Alzen 227 Willenhall

WhiteAd 4108

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Fire-resistant Plastics

ONE OF THE MAJOR LIMITATIONS of most plastics materials is their lack of resistance to fire. It has long been realised that the more chlorine atoms that can be packed with stability into each monomer, the more flame-resistant the resultant polymer would be. Such a highly chlorinated monomer has recently been synthesised in a project at the Stanford Research Institute in California. The monomer, in turn, has been polymerised into a plastics material, polytrichloropropene, which will not support combustion. In addition, the polymer produced has a high melting point, so that it can keep its shape even in boiling water.

Although the new polymer has been moulded and made into films like other plastics, possible uses have not yet been fully explored. However, the basic monomer represents the most promising result of the research project, because it can be copolymerised with common plastics such as polyethylene and polyvinylacetate, adding to these materials the property of flame resistance.

New Composite Materials

THE MODERN TREND in the search for improved materials is towards the mixing of two or more basic materials in such a way that the useful properties of each ingredient are retained without their individual disadvantages.

One promising new class of metallic materials which has been demonstrated by the Battelle Memorial Institute is the lead-cemented alloys made by mixing molten lead with finely divided solid particles of other metals or materials. For example, lead mixed with boron provides an effective nuclear radiation shielding, the lead stopping gamma rays and the boron stopping neutrons. Other applications suggested include corrosion-resistant alloys for chemical engineering, high temperature gaskets and shaft bearings. Lead's softness, sometimes a disadvantage, could be an asset with the new alloys, the lead serving as a binder for dispersing less ductile metals like tungsten or metals with special properties such as magnetic iron powder.

Another way of combining materials is by coating each particle of a powder with a metal. In the search for materials to withstand high temperatures it is usually found that those metals which have good strength at high temperatures suffer from poor oxidation resistance and vice versa. By coating a high temperature, high strength metal with a thin coating of an oxidation resisting metal, the tailoring of composites having specific properties becomes a possibility. The coating of small ceramic spheres with a fusible metal film has led to some interesting experiments in the production of a lightweight, low cost honeycomb reinforcing structure.

Hitherto many other interesting inventions based on coated powders have been hampered by the difficulty of making the coated powder, but Battelle have now developed a process whereby the powder is fluidised in a suitable gas such as hydrogen, and the coating is deposited from a vapour by chemical action. The powder is maintained at a high temperature to allow the plating gas to react. This process is said to be simple and versatile for a wide range of materials.

Improved Steam Condensers

IT MIGHT BE POSSIBLE to build steam condensers of only half the present-day size if the rates of heat transfer obtained in laboratory-scale tests could be achieved in full-scale plant.

Steam normally condenses on the cooling surfaces as a more-or-less continuous film of water, which slows down the rate of heat flow. If the cooling surfaces are treated with special water-repellent chemicals (known as promoters) the steam may condense as separate droplets and a much greater rate of heat transfer is obtained. About seventy promoters have been produced for the National Engineering Laboratory; they are suitable for copper, brass and cupro-nickel cooling surfaces. Under laboratory conditions they remain effective for up to several thousand hours.

Further laboratory trials are in progress to see how different promoters react to various steam conditions when applied to a range of copper-alloy tubes. A special condensing unit is being built so that the effect of promoters on the overall efficiency of a condenser can be measured.

The way that these promoters stand up to practical working conditions has been studied by treating condenser tubes in a cross-Channel steamer and in a power station. The steamer tests were successful but in some of the power-station tests the promoter became ineffective when deposits formed on the treated surfaces. The Laboratory would be pleased to collaborate with other industrial organisations in trying out the compounds under practical conditions.

The promoters have been patented, the patent rights being held by the National Research Development Corporation.

Hydrofoils Influence Ship Design

THE PRINCIPLE of the high-speed planing hull, where at speed, a considerable part of the weight of the craft is taken up not by water displacement but by the action of the flat part of the boat's underside planing on the surface of the water, has been known for many years. Although this type of vessel has a much better speed performance for a given power than with a conventional hull, its flat bottom combined with high speed resulted in poor seakeeping in rough weather.

In recent years development has been proceeding in Germany, Italy and Switzerland with the design of hydrofoil vessels, in which the whole hull is lifted out of the water by submerged elevation surfaces and this action reduces wave-making resistance and cuts down hull friction. Apart from improved performance and reduced fuel costs for a given speed, these designs produce a remarkably smooth ride over rough water, thereby having great advantages for passenger-carrying craft. Although smaller engines can be used for a given size of vessel, the hydrofoil boat demands a particular power requirement for which the diesel engine is not entirely satisfactory. This is because a hydrofoil needs all available power when it is accelerating to "take-off" and lifting the hull out of the water. During this period the propeller is still revolving at relatively slow speeds, a condition when the diesel engine will not provide adequate power. In this field of application the gas turbine, such as the Bristol Siddeley Marine Proteus, would appear to be ideal, for in addition to its light weight and compactness, the engine delivers extremely high power at low or medium propeller speeds. It also gives the vessel extremely rapid acceleration, an important consideration in hydrofoil design.

It is also possible that the introduction of hydrofoils will initiate a new interest in weight control for ships. With conventional designs excessive weight saving has been pointless owing to the necessity for additional ballasting to compensate. With hydrofoils, however, where the ship must be lifted bodily out of the water, designers must be weight conscious.

PICTURE NEWS

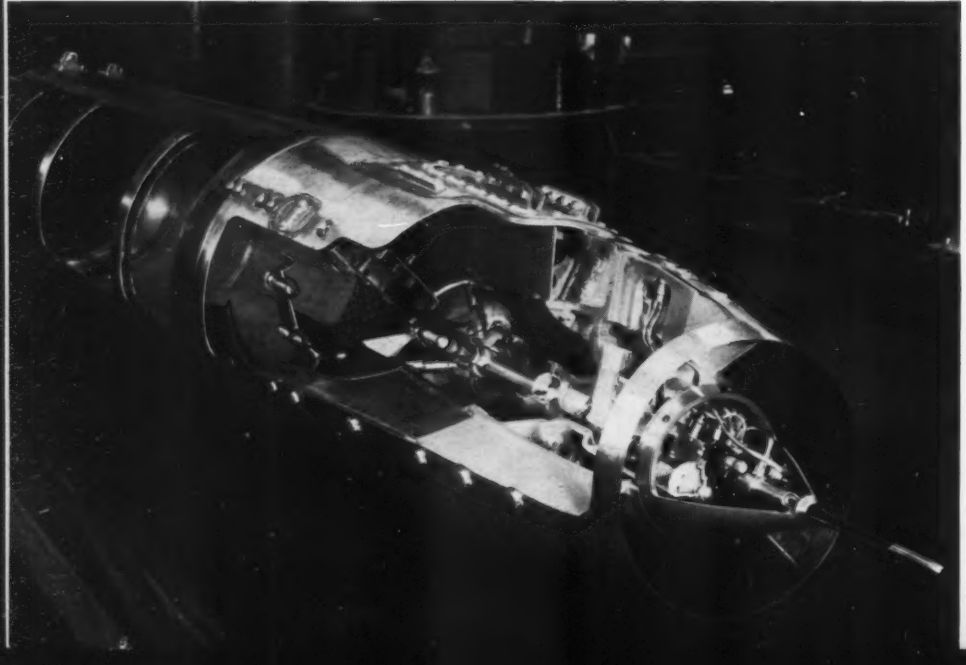
IN THE WORLD OF MATERIALS & DESIGN

NEW SHAPE OF T.V. ◀

These Mullard tubes at this year's Radio Show indicate the trend in T.V. design. All give the same size picture, but the lower tube—one of the 110 deg. scanning types—is 5 in. shorter than the middle one and over 8½ in. shorter than the earlier 70 deg. tube at the top. The shorter tube has made possible this year's slim sets.

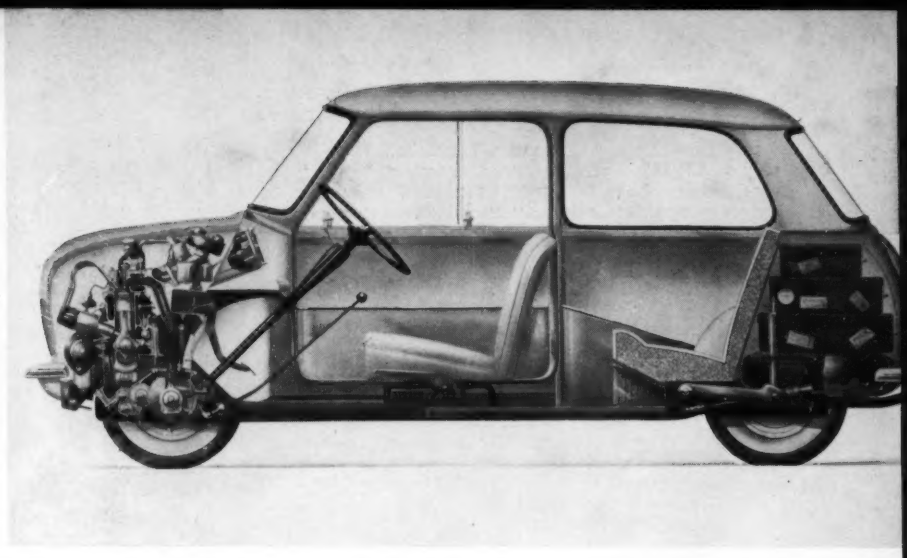
GYRO-HYDRAULIC STEERING ▲

Primary steering control equipment in the new Shell tanker, "Anadara," combines in a single unit the Hastie hydraulic telemotor and the Sperry hand-electric and automatic steering units. As well as occupying less space, the single combined console improves efficiency by central grouping of controls.



INSIDE LOOK AT FARNBOROUGH

Internal details of the Bristol Siddeley Thor BT-1 ramjet were seen for the first time at Farnborough this year. It is a predecessor of the Thor now in production for the Bloodhound missiles which are already in service with the R.A.F. It can develop over 100,000 h.p. at Mach 3.0. With no moving parts, and largely of sheet-metal construction, it is much cheaper to make than a turbojet and more economical on fuel at high supersonic speeds.



BRITISH BABY CAR

Born as identical twins, the new Austin Seven and the Morris Mini-minor are the B.M.C. answer to Continental baby-car competition. Spectacular design features are the transverse-slung engine, a sump housing both the gearbox and the differential, rubber suspension units (independent four-wheel) and universal couplings. It is said to have a top speed of 70 m.p.h., and a maximum petrol consumption of 50 m.p.g.

OXICLES ON STEEL ◀

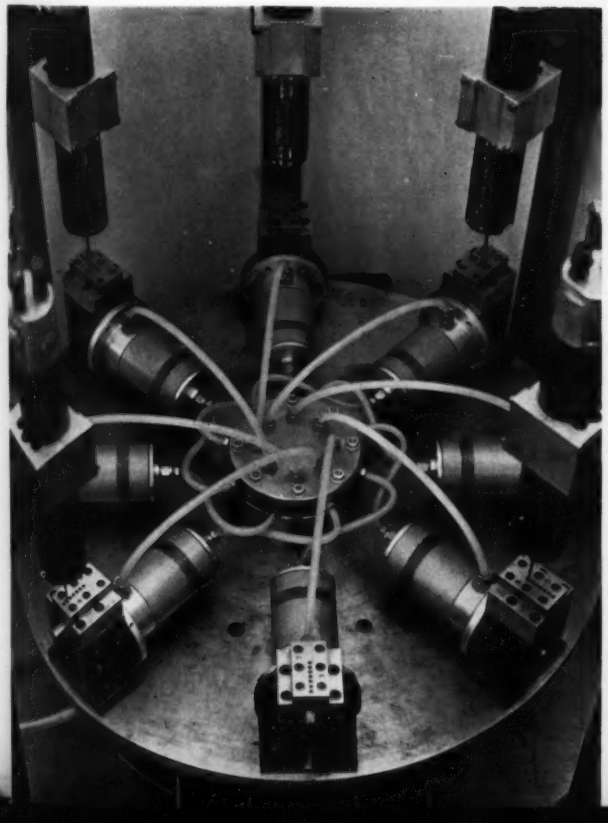
To produce these oxicles on mild steel sheet at Fulmer Research Institute, a specimen was cut from 0.025 in. sheet and one surface mechanically polished to a metallographic finish. It was then oxidised in a flowing atmosphere of steam for ½ hr. at 700 deg. C. Oxicles are grown to study various oxidation effects on heat transfer from a surface in such equipment as heat exchangers.

AUTOMATION AT PARIS ▼

This multi-station rotary transfer machine designed by Centec Machine Tools Ltd. has been shown at the European Machine Tool Exhibition in Paris during September. Here can be seen the arrangement of drilling, feed and ejecting positions on the indexing table, and the layout of the Maxam 2¼ in. clamping cylinders and Par-A-matic power units.

CLOSED CIRCUIT CAMERA

This new Marconi Vidicon type BD 864 closed circuit T.V. camera weighs only 56 lb., about a fifth of the average studio camera. By extensive use of printed circuits, its size is only 14½ in. high by 15 in. long by 10 in. wide. It is fitted with remote focus, pan and tilt facilities and a single lens (optional) system.



New Stress-analysis Technique

ULTRASONICS AND PHOTOELASTICITY are both established techniques in the field of non-destructive testing, but an ingenious combination of the two promises to offer advantages to designers who wish to analyse stresses in a structure or machine part. The new method, known as acoustoelasticity, is being developed by the Armour Research Foundation and depends on the fact that polarised high-frequency sound waves change in angle of polarisation when passed through a part under stress. In this way they behave similarly to polarised light which is used for determining stresses in a transparent model.

The advantages of the new method, it is said, are that there is no need for a plastic model, and that the magnitude of stresses can be evaluated directly. Almost any material can be handled, whether it is metal or non-metal, so long as sound waves can penetrate. A specially interesting feature is that residual stresses can be quickly determined, and as the part is not affected by the test it is believed to be the first successful non-destructive method for analysing these stresses. At the moment the method will not give a direct visual indication of stresses, as these have to be plotted from oscilloscope measurements, but progress suggests that a direct visual method may be developed before long.

Inconel Dies Improve Forgings

CONVENTIONAL FORGINGS have been limited by the fact that the hot blank quickly loses heat in a cold die so that deep cavities of thin section cannot be filled. A further difficulty is that in order to remove the cooled part from the die a steep edge angle must be provided and these shortcomings result in expensive finishing operations. The Armour Research Foundation have announced the successful testing of a new die metal, Inconel 713C, which has been used for forgings at temperatures up to 850 deg. C. and pressures up to 80,000 p.s.i.

It is claimed that the use of hot dies permits forgings to be produced in thinner sections and to far greater accuracy than with cold dies, thus greatly reducing the amount of machining. Owing to the difficulty of machining the new die metal and the impossibility of using standard die-sinking methods, a special casting technique has been developed using a mouldable graphite mixture. This system produced a gas-free strong die with a surface so smooth that it required no finishing operations. A British-made equivalent to Inconel 713C is manufactured by Henry Wiggin & Co. under the name Nimocast 713C.

Improved Commutator Alloy

THE REQUIREMENTS OF COMMUTATORS for rotating electrical machines, especially those used in aircraft, have increased steadily in recent years. In particular the ambient temperature has risen; this has emphasised the need for improved commutator materials. One material which has the desirable combination of properties is zirconium copper, an alloy initially developed in the U.S.A.

Zirconium copper, containing less than 1 per cent zirconium and produced with controlled deformation and heat treatment, has high electrical conductivity and good mechanical properties at room and elevated temperatures in both longitudinal and transverse directions. Two of its outstanding characteristics are resistance to softening during brazing and freedom from notch sensitivity. This latter feature limits the use of conventional high conductivity copper alloys in commutators, which contain severe stress concentration at the dovetail. Further advantages of zirconium copper are good machinability and ease of manufacture.

This alloy, produced both in this country and the U.S.A., has been employed by Rotax Ltd. in a number of their machines. Stringent laboratory tests and service trials have proved successful and show that the enhanced mechanical and physical properties in no way impair the electrical performance. Further development of this alloy will probably lead to its universal application in electrical commutators for use at high temperatures.

New Soviet Plastics

A NEW PLASTICS MATERIAL with very good characteristics is reported to have been developed by the Institute of Polymerised Plastics at Leningrad. Supplied in the form of sheets, the material (which is called S.N.P.) has a high mechanical strength, stability at low temperatures, resistance to heat and stability to chemical action. It can be readily cast, subjected to mechanical working, cemented and polished. It is produced by fusing S.N.-28 copolymer (styrene-nitrile) with S.K.N.-26 rubber.

Evaluating Metals

THE EXPERIENCE OF many manufacturers employing the techniques of cold extrusion suggests that an economic advantage may be found in working metals in the high plastic range beyond the point of normal tensile failure, and in which the working of the metal must be essentially under compression.

No single test procedure has been developed which gives a complete picture of the plastic range and it is necessary to correlate a number of tests in a composite curve. This is shown in a recent paper to the A.S.M.E. While broad areas of application still remain unexplored, the paper accentuates the need for adequate tests of the behaviour of various materials when worked in the high plastic range. Such tests would enable metals to be classified as regards relative formability and would identify the work hardening properties of various alloying elements.

What appears to be a definite step towards the ultimate goal of prediction of alloy properties is the work of a Battelle metallurgist: he has developed a concept that permits rapid determination of the creep or tensile strength of high-purity alloys as well as complex commercial alloys. This concept is based primarily upon the equivalence of the "equicohesive point" of a metal as determined by hot hardness, tensile or creep tests. Normally there is a temperature which separates low-temperature deformation in metals (where fracture is through the grain) and high-temperature deformation (where fracture occurs at the grain boundaries of the metal). Until now this equicohesive temperature has been qualitative because it varies with the speed of the test. It has now been shown that by taking time effects into consideration, the equicohesive temperature becomes fixed. This new equicohesive point has also been found to correlate with the high temperatures strengths and stabilities of alloys. Since strength is related to various basic properties of alloys, these new correlations can lead to better understanding of the basic mechanism involved.

IN NEXT MONTH'S ISSUE . . .

Principal features planned for the November issue of ENGINEERING MATERIALS AND DESIGN include:

Developments in Inorganic Fibres
Application by the designer of refractory fibres.

Choosing Metals and Alloys for Creep Resistance
How their properties may be best utilised.

Resistance Welding in Relation to Design
Potentialities of these versatile joining methods.

Selection of Ball and Roller Bearings
Second part of a survey of bearing materials and components.

Uranium and Thorium in Modern Industry
Their peaceful uses in various branches of engineering.

FOR FURTHER INFORMATION

A.S.M.E. Paper. "High Range Plasticity of Metals beyond Normal Work Hardening". By E. V. Crane and W. S. Wagner of E. W. Bliss (England) Ltd.

Stanford Research Institute, Menlo Park, California, U.S.A.

Battelle Institute Ltd., 24 Ryder Street, London, S.W.1.

Rotax Ltd., Willesden Junction London, N.W.10.

Armour Research Foundation, Illinois Institute of Technology, 35 West 33rd Street, Chicago 16, Ill., U.S.A.

Bristol Siddeley Engines Ltd., P.O. Box 3, Filton, Bristol.

Engineering Materials and Design

A FIRST YEAR IN REVIEW

OCTOBER may seem to be an unusual month for making an annual review. It is probably as good as any other month but to us it has special significance because the first issue of ENGINEERING MATERIALS AND DESIGN appeared exactly a year ago. The first birthday of a new journal is just as important an occasion as that of a child because it represents the successful completion of a difficult and sometimes dangerous period. On the other hand it is a time to look forward, remembering the words of A. A. Milne, "Now I am one I have just begun", and ponder on how we are going to cram into the next twelve issues all the fascinating information and data we come across.

In our first editorial, "The Challenge of Materials", we described our self-appointed task of keeping designers abreast of development in the many subjects of importance to his work and are fully conscious of the fact that we have only just started a task which can never be finished. Many interesting materials, such as tantalum, polyurethane resins and interesting ceramics have as yet received scant treatment but these deficiencies will be made good in the coming months. The pace of developments in new materials and components shows no sign of slackening and therefore it is impossible in a reasonable space to deal comprehensively with everything that is new and at the same time keep an eye on readers' interests in established materials and techniques.

A well-known electrical engineer once said to us: "It is time someone produced a technical journal for the reader"; we have accepted this challenge and hope that we have met it. We do not claim to be one hundred per cent, and indeed we never can, but we are continually trying to find out what our readers really want and we do our best to give it them. We are always pleased to have constructive criticisms and as a result of some of these we have already made a number of minor editorial changes. Obviously we cannot please everyone. This was evident from the replies we received to a questionnaire which was sent out to a random selection of readers, some saying that our articles were not technical enough and others that they were too technical. Nevertheless, we try and cater for all tastes and amongst the many important features planned for the near future are articles on photoelasticity for designers, new inorganic fibres, survey of gasket materials and developments in inorganic insulation. Commencing with this issue we are featuring developments in Russia as we believe that there is widespread interest in them.

We have made many new friends during the past year and we look forward with pleasure to making more in the months to come. We sincerely desire to have personal contact with our readers and we are pleased to try and help with technical problems and location of data.

In response to requests we have increased the number of Reader Enquiry cards in each issue to encourage fullest use of our free service. Interest in this can be gauged from the fact that in our first year we have dealt with over 20,000 enquiries.

The Editor

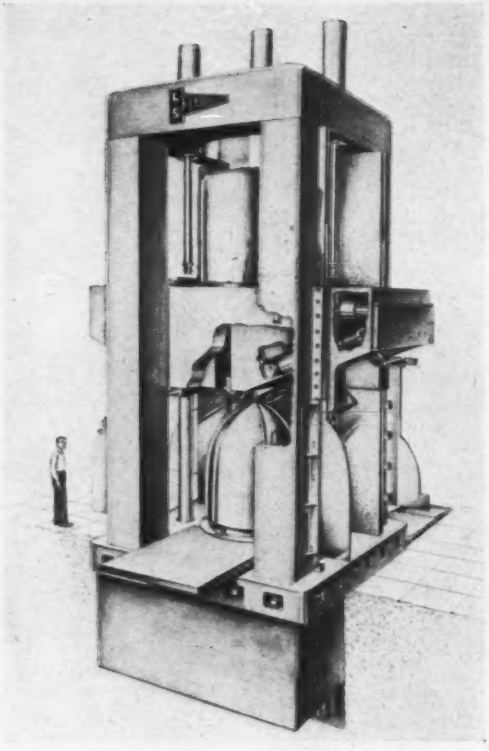


Fig. 1. Lodge & Shipley Quad-trace vertical Floturn machine for producing components 80 in. in dia. and 100 in. long.

FLOW FORMED AND POWER SPUN COMPONENTS

New machines to be introduced soon will widen the possibilities for production of flow formed and power spun components. These are processes which have yet to be fully exploited by the average designer in this country

THE production of metal spinnings, mostly for domestic utensils, was known to the ancients. In this process, a rounded metal bar is pressed against a sheet-metal disc as it rotates with and is pressed against a revolving mandrel by a live tailstock. By the leverage obtained from a long handle on the forming tool held under the arm (and using a metal peg in one of a series of holes in the tool rest as a fulcrum), the operator makes a series of passes across the work and forms the metal to the shape of the mandrel. Operator skill consists mainly in preserving the thickness of the metal.

In recent years this process has undergone considerable development and a number of terms are now used to describe modern production methods of this type. In both power spinning and flow forming, the hand tool has been replaced by one or two rollers, operated by leadscrews or hydraulic cylinders. Both methods have enabled far heavier gauges of metal to be worked and the range of products has been greatly extended.

Power spinning is essentially the same process as spinning by a hand-held tool, as can be seen in Fig. 2(b). A flat metal blank, of larger diameter than the finished component, is worked by a roller round a revolving mandrel, the gauge of the metal being maintained. To produce cones and cylindrical vessels, it will be seen that the size of the flat blank will be a simple development problem, similar to that of a blank for deep drawing. If, however, it is desired to produce a vessel having a thick base and then to extend the walls by pressure of the roller, with a consequent reduction of thickness, then the calculation of blank size is more complex.

In flow forming (variously called Floturning, Hydrospinning and Roll Flowing by different machinery manufacturers), the displacement of the metal is parallel to the centre line of the part being formed. Fig. 2(a) illustrates the process. It will be seen that when a cone is to be produced from flat blanks, its base diameter will be the same or little different from that of the original blank. Plastic deformation of the metal has taken place at right angles to the direction taken in the rolling of steel strip.

In general, machines intended for flow forming only are considerably larger and more powerful than those for power spinning, particularly when the flow forming of conical vessels from flat blanks is intended (Fig. 10). Machines such as that shown in Fig. 1 are at present being developed for work on blanks of up to 1-in.-thick stainless steel for the production of components 80 in. in diameter and 100 in. in length. Flow forming is not confined to the production of conical vessels. Tubular components, such as the types illustrated in Fig. 9, can also be produced by working from a pre-machined blank which is elongated by the action of the roller.

Certain dual-purpose machines have been developed, however, which can be used for both processes. These are particularly valuable in the production of cylindrical components produced from flat blanks, such as those shown in Figs. 4 and 5. The aluminium cylinder in Fig. 4 was power spun from $\frac{1}{4}$-in.-thick material (L 17), the walls being then extended by flow forming. The drilled flange was maintained at $\frac{1}{4}$-in. thickness and the walls were reduced in thickness to $\frac{1}{16}$ in., a stiffening flange 0·08 in. thick being left on the outside of the open end.

Advantages of Power Spinning

Power spinning may be used for such items as hotplate ware with thick bottoms (especially hotel sizes), conical vessels such as milking pails, rocket noses, wire drawing drums, dental chair bases and many others which were formerly made by fabrication or casting. Power-spun components for aircraft and jet engines, in stainless and Nimonic alloys, are in increasing demand and pressure-vessel ends in both steel and aluminium are now produced by this method (see Fig. 8).

Advantages of Flow Forming

The principal advantages of flow forming are the greater economy of operations and the improvement in physical properties that result from cold working. In addition, considerable savings in material are sometimes possible. This is well illustrated in Fig. 3. To produce the 19-lb. component shown by conventional means, it would have been necessary to machine a forging weighing 380 lb.; using flow forming, a machined blank weighing 130 lb. only was required. A further advantage is that the cold plastic deformation, which accompanies the reduction in thickness, results in marked grain elongation and refinement in structure, with increase in mechanical strength. Subsequent annealing, normalising or other heat treatment operations, at temperatures below critical transformation ranges, will re-establish the essential random grain orientation, except that it will be considerably finer in size than that exhibited by wrought material before flow forming. For example, the yield strength of an annealed low-carbon steel, which before flow forming was 54,000 p.s.i., was raised to 75,000 p.s.i. by the cold working, while the ultimate strength was raised from 72,000 p.s.i. to 81,500 p.s.i.

Another example of how flow forming is being used to eliminate costly machining is in the production of parallel and conical components, ribbed both internally and externally. Pratt & Whitney Inc. have produced large engine castings, ribbed externally and indented internally, using mandrels 12 in. in diameter and 15 in. long (Fig. 12). The mandrel is smaller than the inside diameter of the components, the latter running eccentrically during the ribbing process. The difference in size is essential to enable the component to be removed. Some ribbed components of this sort are produced from a welded and pre-machined wrapped strip which is then elongated and ribbed by flow forming. The savings over conventional methods of welding together a pile of machined rings will be readily appreciated, especially when the improved physical properties resulting from the process are taken into account.

A further advantage of flow forming is that it is now possible to produce components for which it would be difficult to devise an alternative production method. The Explorer satellite nose cone, in 430 stainless steel, the production stages of which are shown in Fig. 7, provides a good example.

Manufacturing Rules and Expressions

The rules governing the production of cones from flat blanks or pre-machined or flow-formed cones into more acute cones are as follows:

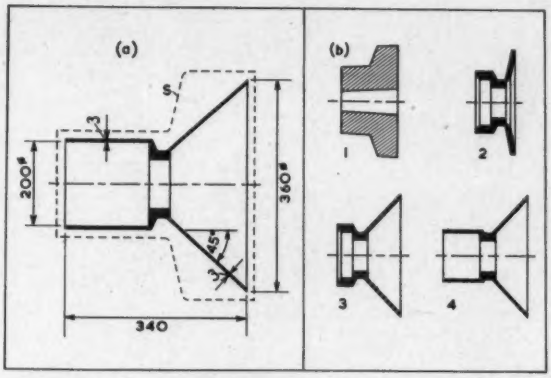


Fig. 3. Material that may be saved by using flow forming. (a) shows size of forging necessary (weighing 380 lb.) to produce component by conventional machining. (b) shows stages in producing same component by flow forming a pre-machined forging weighing only 130 lb.

THE SINE LAW—If T is the original blank thickness and T_1 is the wall thickness of the flow-formed part, then:

$$T = T_1/\mathrm{Sin}\alpha \qquad \text{(see Fig. 6)}$$

For forming a more acute cone from another cone with an angle θ, then:

$$T_1 = T_2\frac{\mathrm{Sin}\,\theta}{\mathrm{Sin}\,\alpha}$$

(See Fig. 6)

DEFLECTION—The pressure that must be exerted by the roller against the mandrel in flow forming gives rise to deflection of the mandrel. The difference between the setting made to obtain a certain wall thickness and the actual wall thickness after flow forming is termed the deflection. In machines which employ twin rollers this deflection is greatly reduced. It must be remembered, however, that for certain kinds of work (e.g., internally ribbed components) it will always be necessary to employ a single roller machine.

REDUCTION—The material thickness reduction is referred to as a percentage, and is the difference between the thickness of the flow-formed part and the original thickness expressed as a percentage of the original thickness and is the actual reduction that takes place.

It is essential that the reduction be calculated before the flow forming is commenced, as it governs the setting of the roller in relation to the mandrel. This is termed

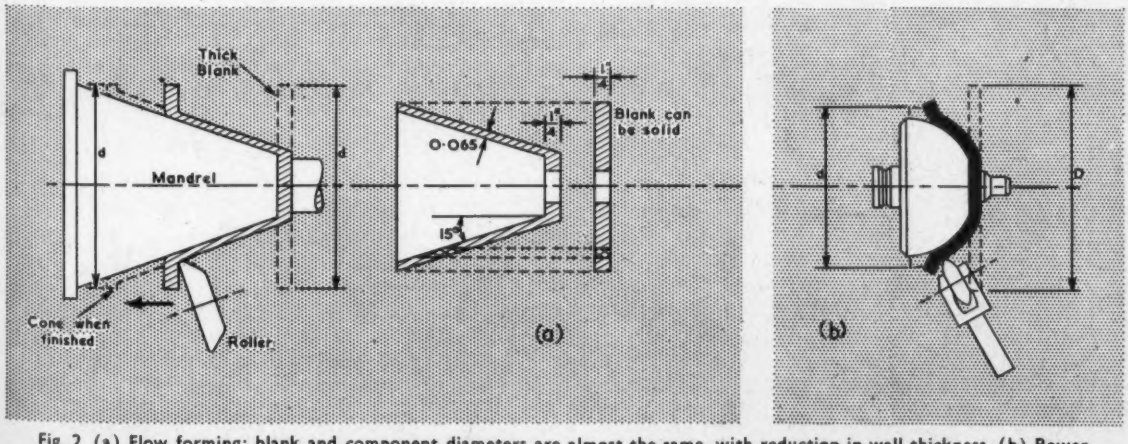


Fig. 2. (a) Flow forming: blank and component diameters are almost the same, with reduction in wall thickness. (b) Power spinning: blank diameter is larger than finished component, the wall thickness of the component being the same as the blank.

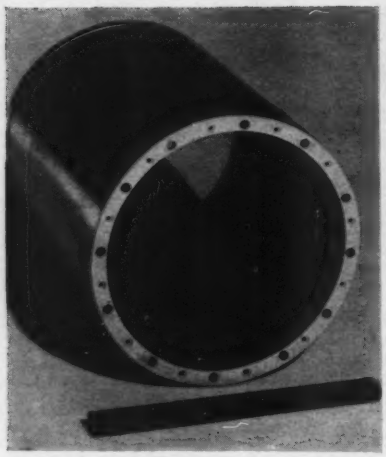


Fig. 4. Far left. Cylinder in aluminium (L 17) power spun from ½-in. blank and then flow formed to $\frac{1}{16}$ in. wall thickness, leaving 0·08-in. flange at open end.

Fig. 5. Left. Stainless-steel tube of 0·026 in. wall thickness flow formed from 0·036-in. tube on Leifeld machine. Right. Swedish iron component power spun from 0·048-in.-thick blank, then flow formed to elongate walls and reduce thickness to 0·012 in. (Photos: Drakesons (General Metal Spinners) Ltd.)

the "setting reduction". It is always greater than the actual reduction, as it ignores the deflection which takes place.

Although the above rules have been shown to apply for all types of steel and aluminium, it has, however, been proved that flow forming can be carried out with a range of reductions which varies according to the material and the design of the part. But this range of reductions should only be considered where the design of the part does not allow the sine law to be applied, or where a tapered wall thickness is required.

Materials

To qualify for either power spinning or flow forming, a good degree of strength and ductility are necessary in the component materials. Nevertheless, some materials not readily formed by drawing or machining do exhibit a higher degree of formability when produced by these methods. Most mild to high-carbon steels are suitable for the process. As carbon content increases, so must the percentage of alloy with other metals to produce a grain structure which will withstand the high degree of compressive plastic deformation without failure. In the case of mild steel it seems that a minimum carbon content of 0·1 per cent is necessary for flow forming. Although all types of steel can be formed into simple cones, the different characteristics become more apparent when it is necessary to produce parallel-sided components or those having flanges.

In general, it has been found that the closer the proof stress-ultimate stress ratio approximates to unity, the more difficult it is to work by flow forming. The new steel F.V.448, which was specially developed as a low-expansion creep-resistant steel for jet engine parts and has a U.T.S. of 76 t.s.i. with 0·1 per cent proof stress of 57 t.s.i., would probably be unsuited to flow forming, as its proof stress would be rapidly raised by the cold work involved to the point of unworkability. Unfortunately, this kind of characteristic is common to creep-resistant alloys. As the actual amount of cold working depends on the shape of each component, it is difficult, without actual experiment, to say with certainty just how a particular material will behave in a certain application. Only experience will give

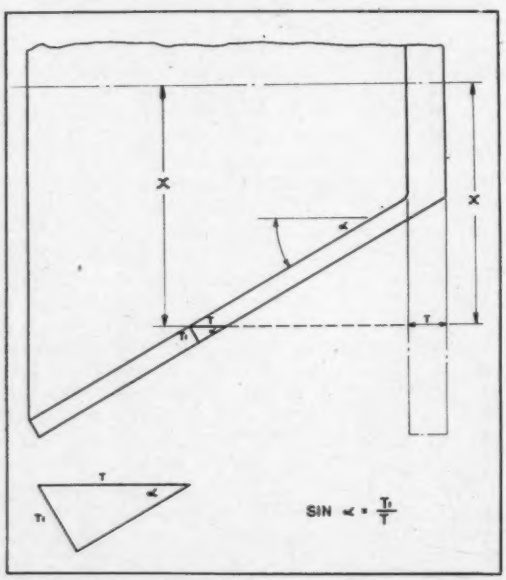


Fig. 6. Basic formula used in flow forming process. T = original blank thickness; T_1 = wall thickness of finished component.

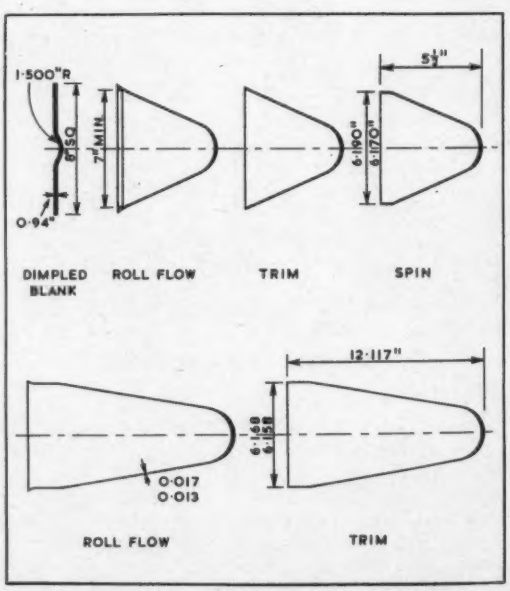


Fig. 7. Stages in the production of the Explorer satellite nose cone produced by flow forming on a Lodge & Shipley machine.

Fig. 8. Stainless-steel and Nimonic components produced on a Leifeld heavy-duty spinning lathe.

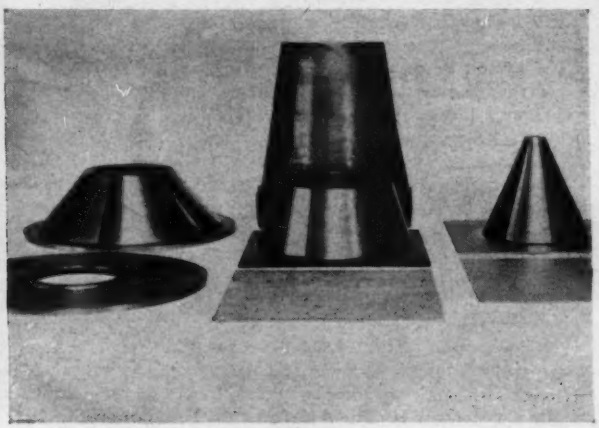


Fig. 10. Stages in the production of steel conical components by flow forming. (Photo: Wilmot Breeden Ltd.)

the necessary guidance.

In the case of stainless steels it has been found advantageous to limit the chromium content to a maximum of 18 per cent, so as not to restrict the capacity of the material for cold work. All stainless steels seem to exhibit a good degree of flowability, but the degree of cold reduction possible is generally not as high as with other steels.

Experience in this country has shown that in the parallel flow forming of high-carbon steel tubes, such as those illustrated in Fig. 9, annealing between passes is essential.

Most wrought aluminium can be flow formed. Much experimental work is being done on flow forming aluminium alloys immediately after heat treatment, when full hardening occurs by ageing after working.

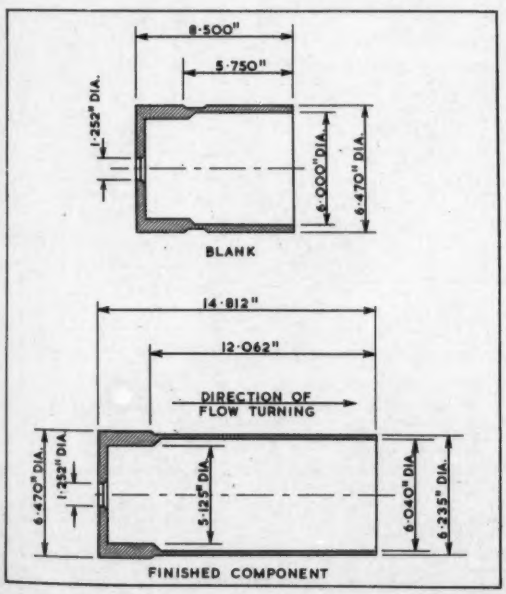
Work done on titanium, magnesium and molybdenum indicates that flow forming must be carried out hot. On some machines it is possible to use flame or induction heating as the work is being done.

When welded cylinders, such as those shown in Fig. 8, are worked, it is essential that the welds are of the highest quality. Any slag inclusions or voids in the weld will cause a failure under flow forming. In the U.S.A., centrifugally cast rings of AISI 4130 and type 304 stainless steel are reported to have been reduced 80 per cent in thickness, with complete transition from cast to wrought grain structure.

Thin-walled cones and shallow dished components have been produced in Nimonic and Inconel alloys of nickel, and Nimonic 75 and 80 have been successfully power spun and in some cases flow turned. But flame chambers and other components for jet engines (for which these alloys were originally developed) must be produced to shapes of such difficult configuration and to such accuracy and wall thicknesses that they are at present still made by pressing and welding operations. Recent developments in flow-forming machines, however, which enable complex curves to be produced, may possibly alter this position.

U.K. and Foreign Practice

Power spinning is already a well-established process in this country, where machines of German manufacture are



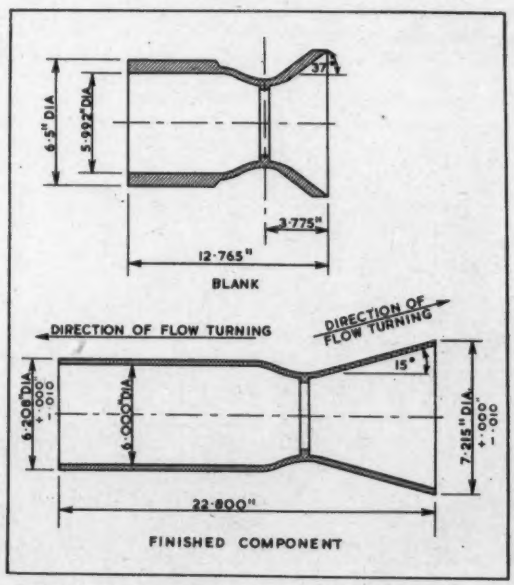


Fig. 9. Blanks and finished components produced by Wilmot Breeden Ltd. on a Lodge & Shipley No. 40 machine with (left) S.A.E.4130 and (right) Fortiweld.

used. They have greatly extended the range and size of components that the contract spinner can produce, to include such items as jet-engine cones and dished ends for pressure vessels. In some instances, components to considerable limits of accuracy are produced by power spinning followed by conventional machining, the lathes being easily adapted to take cutting tools.

Numerous components are produced for the consumer, hospitals, dairies (milk churns, for example) and the aircraft industry. Components formerly made from large machined castings or from fabrications are being produced increasingly in this new way.

Large flow-forming machines, of the size introduced by Lodge & Shipley and Cincinatti, are very few in number in Britain, although the position in the U.S.A. is markedly different. Experience gained in this country with Lodge & Shipley machines suggests that, although technically the process is of undoubted value for the production of certain components for the aircraft industry, orders tend to be on a smaller scale than in the U.S.A. Mandrels and rollers for flow turning are costly items and must be made from hardened and ground tool steel, owing to the large forces encountered. It is essential, therefore, that components be required in reasonable quantities to justify the high tool cost involved. Each component requires special treatment, and a great deal of experience is being gained by the owners of the few machines of this sort. This experience, combined with the vital tool design knowledge, will undoubtedly pay off in the long run when the immense potentialities of the process are more fully realised.

Unfortunately, designers tend to think only in terms of familiar production methods. To appreciate flow-forming possibilities, it is necessary to think of the material not so much as a mass to be reduced by a cutting tool to a given size, but more as a piece of clay to be formed as on the potter's wheel. When the process has been witnessed, it is possible, with close co-operation between design and production departments, to revise some designs intended for conventional means of production, or originate new ones to suit the process.

Serious consideration is already being given, both in the U.S.A. and this country, to the making of such motor-car parts as wheels and hub caps. Those about to embark on the design of awkward-shaped cones, tubes flaring into cones, venturis and thick-walled or ribbed cylinders should bear the process in mind.

It appears likely that the experience necessary for success will probably lead to the process becoming, like metal spinning, a specialist one limited to certain manufacturers who carry out little else. The kind of skill required will probably lead to flow forming becoming an extension, with power spinning, of the general metal spinner's art.

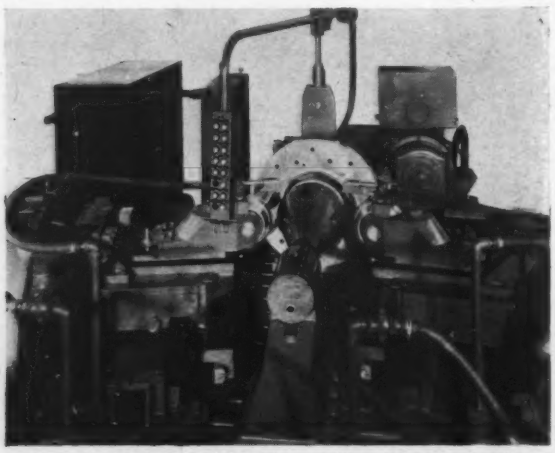


Fig. 11. Cincinatti Hydrospin machine for flow forming components up to 42 in. dia. by 50 in. long. Hydraulic tracer attachment can be fitted.

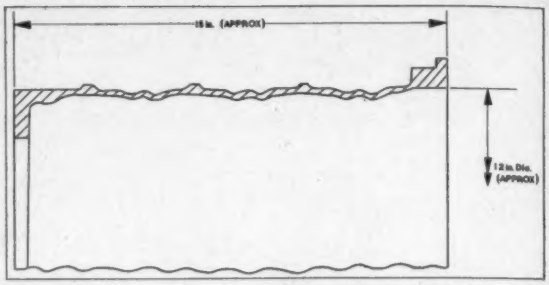


Fig. 12. Section of large compressor casing, ribbed both internally and externally, produced from wrapped and welded flat material.

Recent Developments

In both power spinning and flow forming recent developments have been towards machines capable of following contours, either by following the form of the mandrel through the metal being formed, as in the Leifeld machine, or by means of template-following devices. In the latest Boko, Lodge & Shipley and Cincinatti machines (Fig. 11) for flow forming, this feature has made possible the following of difficult contours, in some cases semi-automatically. Another recent trend has been towards introducing vertical machines using two rollers and four templates. A semi-automatic vertical machine by Lodge & Shipley is to be manufactured soon in this country. Very large machines, such as that shown in Fig. 1, are in the project development stage.

ACKNOWLEDGMENTS

We acknowledge with thanks the valuable assistance given with this article by Mr. C. L. Sporck, vice-president, Lodge & Shipley Ltd.; Wilmot Breeden Ltd.; and Drakesons (General Metal Spinners) Ltd.

FOR FURTHER READING

W. Basch, "German Developments in Flowturning", *Metalworking Production*, July 18, 1958, 1247-51.

R. C. Paret, "How Roll Flowing Works", *Metal Forming and Fabricating*, October, 1958.

"Explorer Spotlights Roll Flowing", *American Machinist*, March 24, 1958, 106-10.

"Spinning Titanium Pressure Vessels", Fred Spiegl, *Western Metals*, November, 1957, 48-49.

J. A. Grainger, "New Techniques in Sheet Metal Forming", *I.P.E. Journal, September*, 1957, 593-606.

R. I. Shore, "Floturning Jet Engine Parts", *Modern Machine Shop*, January, 1956, **28**, 136-38.

R. G. Longley and W. Hadley, "Metal Flow Turning", *Sheet Metal Industries*, August, 1956, **33**, 519-29.

"Flow Turning", *Aircraft Production*, October, 1954, **16**, 402-403.

A. R. Teiner, "Spinforming Stainless Steel", *Machine Design*, January, 1955, **27**, No. 1.

"Hydraulic Spinning", *Aircraft Production*, July, 1955, **17**, No. 7.

C. L. Sporck, "Roll Flowing Saves Operations and Costs", *American Machinist*, March 29, 1954, **98**, 104-107.

J. R. Young, "Present-day Techniques of Spinning Aluminium", *Machinery* (U.S.A., April, 1954, **60**, 194-201.

C. L. Sporck and W. H. Busch, "Floturn—a Production Process as well as a Development", A.S.M.E. Paper 57-5A-98, June, 1957.

MANUFACTURERS

The principal flow-forming machines available are:

Bohner & Kohle (U.K. agents: Press & Shear Machinery Co. Ltd.): Heavy-duty spinning lathes, with either manual-or hydraulically-operated slides. The larger machines can be used for flow forming. Oval attachments are available. Tracer controlled.

Cincinatti (U.K. agents: Hordern, Mason & Edwards Ltd.): Very large single- and twin-roller flow-forming machines with tracer attachment.

Leifeld (U.K. agents: Embassy Machine & Tool Co. Ltd.): Large range of power spinning lathes with form-following equipment in the hydraulic models. Oval attachments available.

Lodge & Shipley (U.K. agents: E. H. Jones Ltd.): Large single-roller machines for flow-forming, now fitted with tracer attachment. Twin-roller vertical machine having four template followers suitable for semi-automatic production. Very large machines, for producing components up to 80 in. in dia., in course of design or development.

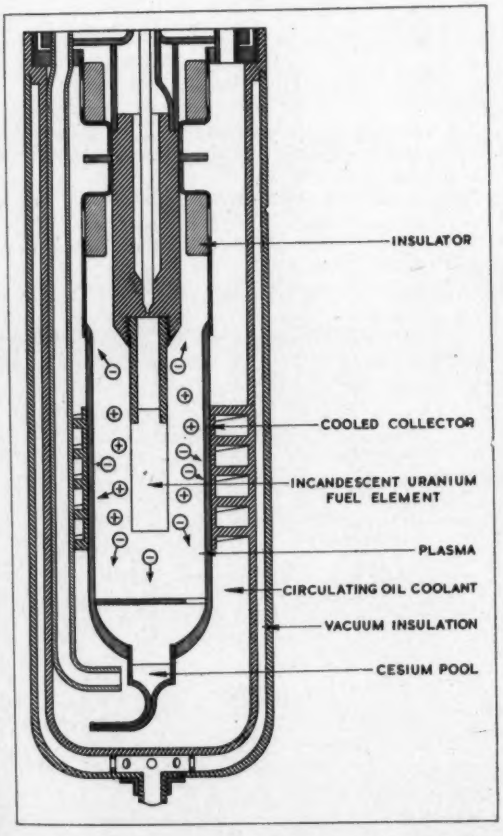
A. B. Hallarydsverken, Sweden: Twin-roller "bulging" lathe.

MORE EFFICIENT THERMOELECTRIC MATERIALS

Though the principle of thermoelectric power is not new, recent developments in materials have made its exploitation more practical

THERMOELECTRIC effects, the direct conversion of heat into electrical energy, have been understood for many years, but because the metals in which they occur are good conductors of heat and electricity their maximum efficiency is limited to about 1 per cent. To improve the efficiency it is necessary to find materials with a low thermal conductivity to reduce flow of heat from the hot to the cold junctions and also a high electrical conductivity to minimise I^2R losses.

In most pure metals and many alloys the heat conductivity is directly related to the electrical conductivity so that an all-metal system cannot on theoretical grounds give a high conversion efficiency. Recent work on semiconductors such as germanium and silicon has shown that these materials can have high thermoelectric powers although their use as commercial generators is limited by their poor electrical conductivity. Compounds such as bismuth telluride and alloys of zinc antimonide and bismuth antimonide have shown more promising characteristics because they combine high thermal e.m.f. with good electrical conductivity.

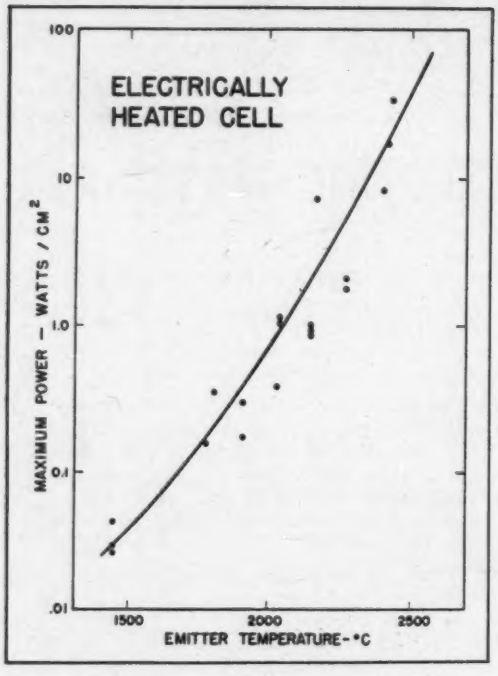


Cutaway diagram (approximately actual size) of the complete plasma thermocouple cell as it was used in the Los Alamos experiment to produce electric power directly from fission heat.

The ability of ceramics to withstand high temperatures is well known and new ceramic-type materials are the first solid-state thermoelectric substances to operate with useful efficiencies at temperatures in the range of 1,100-1,650 deg. C. These materials are described as mixed valance compounds of the transition metals and are said to be inexpensive, easily available and simple to prepare. Being ceramics, they are inherently stable and chemically inactive even at elevated temperatures, and they do not require chemical preparation to an extreme degree of ultra-purity.

One of the latest and most interesting developments is reported by the Los Alamos Laboratory, where a plasma thermocouple has been produced. In this device one of the metallic elements of the couple is replaced by an ionised cæsium gas (plasma) and the output is claimed to be several hundred times greater than that of the earlier all-metal thermocouples. The plasma thermocouple is really a diode. It is well known that thermionic emission into vacuum is accompanied by a Peltier cooling of the vacuum metal interface. The interface may be thought of as a junction between two conductors, the metal and an electron gas whose distribution is determined primarily by the space charge. The addition of a small amount of easily ionised gas to the vacuum region does not affect the Peltier cooling of the interface, but it does squeeze the space charge region to about one micron and replaces most of the electron gas by a low-resistance plasma. The generated e.m.f. of the plasma thermocouple is very much higher than any metal-to-metal device, and a figure of 3 volts is theoretically possible for a temperature difference of 2,000 deg. C. The thermodynamic efficiency of the plasma thermocouple is high, and although it is not quite a Carnot engine (because of the Thomson heat which is absorbed or evolved in the plasma) the theoretical efficiency is not much below the Carnot efficiency. This means that efficiencies of 25 per cent or more are possible.

Thermoelectric power is still in an early stage of development, but at the recent Transistor Exhibition Wayne Kerr Laboratories Ltd. were showing a Russian junction-type converter mounted on the chimney of an oil lamp, supplying electric power for a radio. Solar cells using silicon have been used for supplying power on portable radios, satellites and telephone relay stations, but the latest information from the U.S.A. suggests that organic dyes will replace hyper-pure silicon in this application, and higher efficiencies are claimed.



Relationship between electrical output and emitter temperature of the Los Alamos cell.

Thermoelectric refrigeration is also under active investigation and Russian sources claim efficiencies of 10 per cent. The temperature drop that can be achieved decreases with increasing load for a given set of material parameters. For a single unit the useful cooling at the cold junction can be calculated from the following:

$$Q = IT_c(\alpha_1 - \alpha_2) - \tfrac{1}{2}I^2\left(\frac{P_1L_1}{A_1} + \frac{P_2L_2}{A_2}\right) - \left(\frac{K_1A_1}{L_1} + \frac{K_2A_2}{L_2}\right)T_h - T_c$$

where subscripts 1 and 2 refer to the negative and positive legs of the couple.

- Q Useful cooling
- I Current flowing through the junction
- T_c Temperature of the cold junction (°K.)
- α_1, α_2 Thermoelectric power of dissimilar materials comprising the junction
- P Resistivity
- L Length of thermocouple element
- A Cross-sectional area
- K Thermal conductivity
- T_h Temperature of the hot junction (°K.)

Although it may be many years before thermoelectric cooling can compete with existing refrigerators for large-scale applications such as food storage, there are many technical uses where they may be convenient for cooling small areas, such as rectifier junctions and instruments. Their simplicity and light weight also open up interesting possibilities for cooling applications in aircraft and missiles.

EPOXY LAMINATE USED IN NEW TV TUBE

TELEVISION glass bulb manufacturers in the U.S.A. agreed last year on a design change that would replace the usual flat pane safety glass with a formed implosion panel laminated directly to the T.V. tube face. The most serious problem associated with the innovation was the method of cementing the panel to the tube.

The requirements for a suitable adhesive were that it should be strong and flexible enough to withstand shock of implosion and normal shipping hazards, stable to extreme changes in humidity and temperature, highly adhesive to glass, acceptable to recognised colour standards for television, and adaptable to mass-production techniques.

A special epoxy resin/hardener system devised by the Dow Chemical Co. has been approved by several glass and tube manufacturers. The liquid resin used is cross-linked with the hardener to form a thermoset solid with outstanding dimensional stability. Because the mixture is a water-thin liquid at application temperature, it is conveniently fed into a space between the implosion panel and the tube face.

In testing the system, flat glass laminates were heat aged and evaluated for various properties, and it was found that:

1. Nearly 15 tons of force would be required to separate a standard 21-in. tube from an implosion panel.
2. Life expectancy is estimated to be more than five years at 71 deg. C. and much longer at 38 deg. C.
3. Laminated resin shows no perceptible discoloration after ageing 4,000 hours at 74 deg. C.
4. The resin-to-glass bond is greater than the internal strength of the resin itself. There is no loss of adhesion on ageing.
5. Repeated temperature cycling from −40 deg. C. to room temperature to +71 deg. C. has no effect on laminate properties.
6. The resin maintains adhesion to glass particles even when panels are deliberately cracked and the tubes imploded.
7. Resin colour is apparently unaffected by ordinary exposure to X-rays or ultra-violet light.

More specific properties are given in the accompanying table.

During assembly, the tube and face panel are fastened securely to facilitate handling, with a minimum 0·060-in. space between for the resin. The assembly is then heated to 99-110 deg. C. by forced air oven, infra-red lamp or radiant heater, and the resin-hardener is applied.

Properties of the cured resin/hardener system

Bond strength (lap shear) glass/glass	135 p.s.i.
Ultimate tensile strength, −4°C.	125–135 p.s.i.
Elongation in rupture	300%
Elastic recovery	95%
Shore A-2 hardness	15–20
Refractive index, $N_D25°$	1·5151
Volume resistivity	10^9 ohm-cm.
Dielectric constant, 10^3 c.p.s.	8·26
Dielectric constant, 10^5 c.p.s.	5·87
Dissipation factor, 10^3 c.p.s.	0·0933
Dissipation factor, 10^5 c.p.s.	0·0915
Thermal conductivity	1·2 B.t.u./hr./ft.²/°F./in.
Cubical expansion coefficient (−20°C. to 100°C.)	$0·67 \times 10^{-3}$
Colour stability, several months at 74°C.*	Excellent
Colour stability to intense X-ray radiation*	Glass discolours
Colour stability, 6 month exterior exposure*	Excellent

* Exposed in television-glass sandwich.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Sonic Valve Simplifies Pneumatic Conveying System

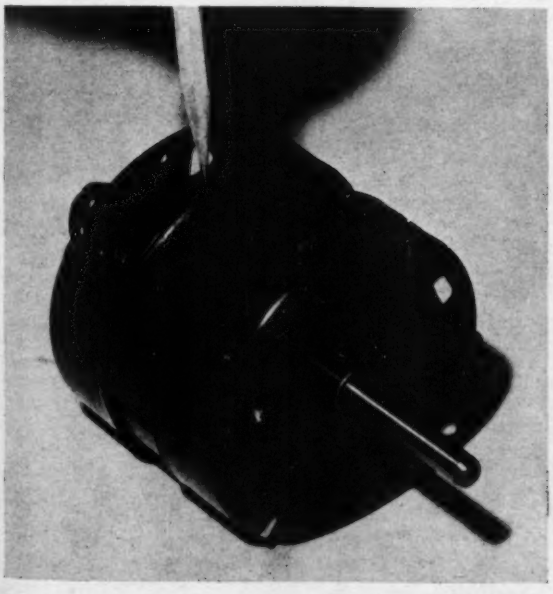
WHEN materials are conveyed pneumatically between different parts of a plant, it has hitherto been necessary to provide a separate compressor for each blowing line. If several lines were powered from a single compressor, it was found that the air tended to take the path which offered the least resistance, and heavily-loaded lines were by-passed and became blocked. Such a system was therefore unacceptable and individual compressors were used, with the inevitable multiplication of driving motors and consequent lower power factors and efficiencies and increased costs of installation and maintenance.

The Simon sonic valve consists of a convergent-divergent nozzle so proportioned that the air passing through reaches the velocity of sound. It is based on the thermodynamic principle that when the velocity of gas through a constriction is equal to the velocity of sound, the mass-flow remains constant, irrespective of downstream resistance. With a sonic valve interposed between a loaded line and the compressor, a pressure wave travelling towards the compressor as a result of a load change is halted at the valve throat, since the wave velocity of propagation is exactly equal to the opposing air velocity. In other words, the sonic valve introduces a sound barrier between the compressor and the varying line resistance.

By carefully selecting the correct profile and by paying particular attention to surface finish, the manufacturers claim that the high pressure loss associated with a simple orifice constriction has been reduced to a negligible proportion. Furthermore, it has been found that this loss is generally more than compensated by the gain in efficiency achieved by using compressors unsuitable for single blowing lines of the conventional type.

The accompanying illustrations show the latest Simon sonic valve with variable throat and a group of valves (painted white) in a bulk-handling system at the Liverpool bakery of William Crawford & Sons Ltd.

Small Motor Assembled in Resin Bonding



IN a new range of small shaded-pole and permanent-split capacitor motors, recently developed in the U.S.A. by the General Electric Co., improved efficiency of up to 40 per cent is claimed. Smaller in size for a given output than motors of traditional design, these motors enable either higher output for the same size input and temperature rise or lower current input for the same size output and temperature rise.

The unitised construction of these motors begins with a reversal of the traditional sequence of operations. The correct air gap between rotor and stator having been determined, the motor is built around this gap to ensure minimum noise and maximum starting and running efficiency.

Notable features of the design include a specially-developed resin of high mechanical strength and good dielectric properties which coats the entire stator core. The core laminations are then fused into a complete and integrated unit which is claimed to be unaffected by humidity. After winding, the stator is further processed with epoxy varnish.

The sleeve bearings employ a capillary oil retention system, are permanently aligned in the manufacturing process and are rigidly supported by the end shields. The oil retention is such that re-oiling is only required annually.

Bunker Vibrator Ensures Smooth Discharge without Arching

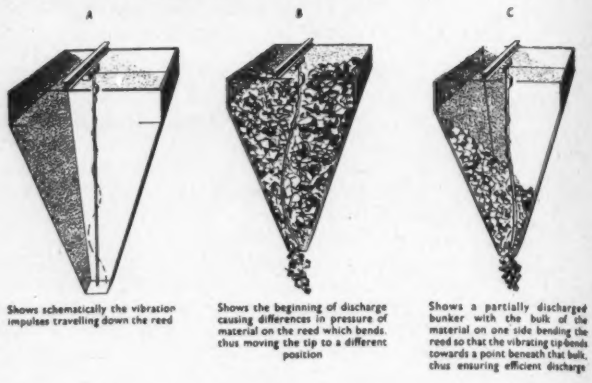
THE tendency of powdered, granulated and lump materials to arch, pack or funnel can, it is claimed, be effectively prevented with the Sinex internal bunker vibrator.

The device consists of a rotary electric vibrator attached to a steel reed which hangs down into the bunker. The complete assembly is suspended from a rolled-steel joist across the top of the bunker by means of anti-vibration mountings which isolate the hopper structure from vibratory effects. When the equipment is in operation the vibration passes down the reed with increasing amplitude, reaching a maximum at the lower end of the reed where the material has a tendency to arch. As vibration loosens and releases the material, the pressure of the latter on the reed varies and causes it to bend and move about the hopper. Vibration is therefore always applied at the most needed point.

Constructed of mild steel, the reed is made up to suit the depth of the hopper for which it is required. Its dimensions vary between 18 and 24 in. wide, $\frac{1}{8}$ to $\frac{3}{8}$ in. thick and up to 60 ft. in length.

The equipment is stated to be particularly effective when applied to coal or ore bunkers and also overcomes the problem of discharging large concrete bunkers where external vibrators cannot be applied. In addition, it can be combined with external vibrators for dealing with very difficult materials.

Special advantages include accessibility of the power unit, ease of replacement when necessary and the fact that it offers no obstruction to material in the hopper.

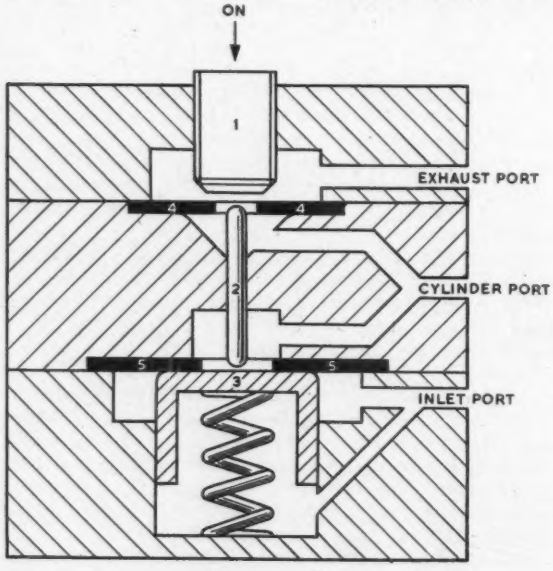

A
B
C
Shows schematically the vibration impulses travelling down the reed
Shows the beginning of discharge causing differences in pressure of material on the reed which bends, thus moving the tip to a different position
Shows a partially discharged bunker with the bulk of the material on one side bending the reed so that the vibrating tip bends towards a point beneath that bulk, thus ensuring efficient discharge

New Air Valves use Neoprene Diaphragms

A NEW system of diaphragm poppet actuation forms one of the principal features of a new range of air control valves recently introduced by Air Automation, Wolverhampton.

The chief advantages claimed for these valves, apart from moderate initial cost, are an extremely positive and leak-free operation, virtually unaffected by any wear on component parts, together with the ability to be serviced very quickly and economically.

The accompanying sectional sketch illustrates the working principle. It will be seen that sealing is effected by neoprene diaphragms and gaskets and does not rely on close tolerances, metal-to-metal seatings or on O-rings. Depression of the operating detent (1) first seals the perforated neoprene diaphragm (4) and then operates the connecting rod (2), which in turn depresses the spring-loaded inlet seal plunger (3), allowing air from the inlet port to pass to the air cylinder or other appliance.



SECTION SHOWING VALVE IN EXHAUST POSITION—INLET CLOSED

The valve bodies consist of a base block and head block and the standardisation of these enables the actuation of the valves to be altered (e.g., from roller to hand lever). In the case of three-way valves it is possible to turn the top block through either 90 or 180 deg. in relation to the base block by simply removing four screws. This gives a useful variety of positions for the actuating mechanism, or of the pilot port in relation to fixing holes and inlet port.

The valve stems, diaphragms, etc., in both three-way and four-way types are for a given size ($\frac{1}{8}$ in. or $\frac{1}{4}$ in. B.S.P.), so that there is no difficulty with regard to variety of spare parts.

An Ultrasonic Kitchen Sink

WHEN transmitted through a liquid, ultrasonic vibrations can be made to clean and degrease a wide variety of materials and in recent years this principle has been utilised for industrial cleaning.

A new type of kitchen sink in which dishes can be washed ultrasonically has been produced experimentally by Westinghouse in the U.S.A. It has been made possible by the development of a new and improved magnetostrictive transducer for changing electrical energy into mechanical sound vibrations above the range of human hearing.

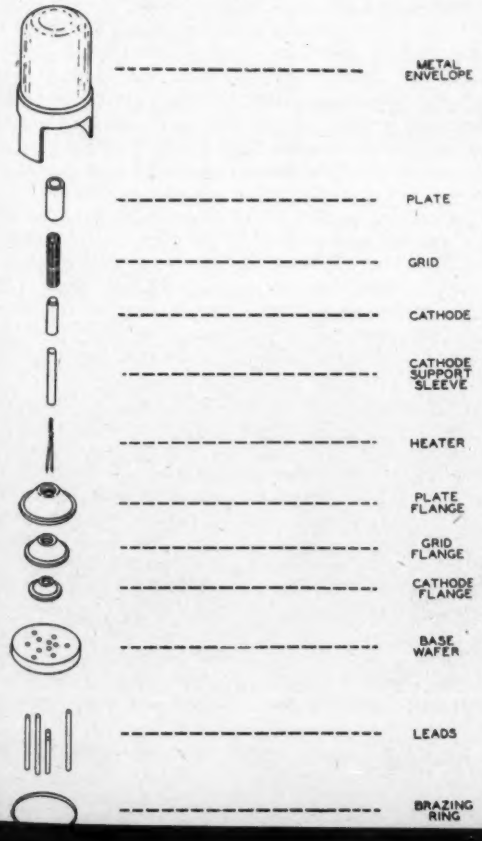
The cavitation principle upon which the sink depends for washing dishes and glasses involves the rapid formation and collapse of minute bubbles or cavities within the liquid being energised. The gas trapped within the minute bubbles undergoes great stresses as the vibrations pass through the liquid, and it is estimated that instantaneous pressures as high as 75,000 p.s.i. and associated temperatures as high as 11,000 deg. C. are produced.

The new Westinghouse transducer has spaced laminations, and instead of vibrating with a wave-like motion, the whole unit pulses in and out with a piston-like movement, and it is claimed that twice the usable ultrasonic power for the same electrical input is provided than with existing types.

Glass and Mica Eliminated in Radio Valve

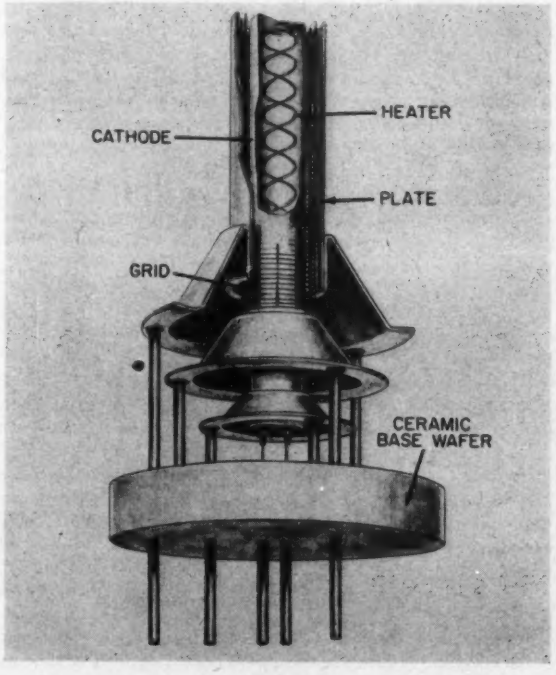
THE accompanying illustrations show the construction principles of the Nuvistor range of radio valves recently developed by the Radio Corporation of America. The new design is claimed to be a major advance, not only in the reduction in size, power drain and in improved performance generally, but is considered also to have outstanding advantages from the highly mechanised production standpoint.

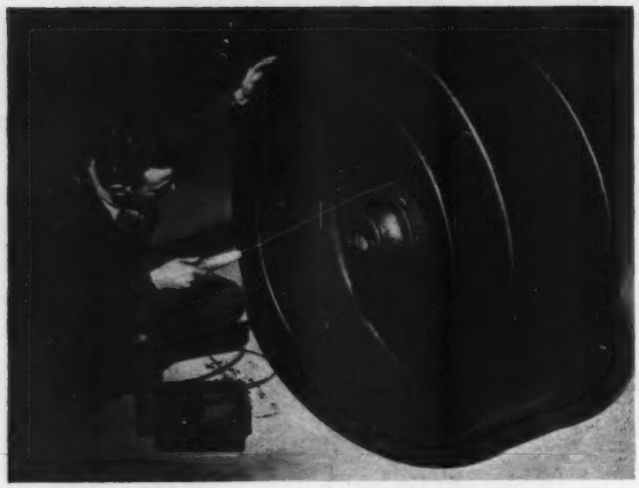
The system of construction used eliminates the need for support discs or spacers. This is achieved by supporting the electrodes, each one of which is a small light cylinder, in a cantilever fashion from the base of the valve, which is a strong ceramic wafer.



All the joints in the valve are processed at white heat in a brazing furnace and then in a vacuum exhaust furnace the air is removed. The manufacturers state that de-gassification at high temperature enables the valves to be used at higher operating temperatures than is possible with the conventional glass and mica system of construction. By accurately positioning and securing the tube elements prior to brazing, the possibility of shorts developing is claimed to be greatly reduced. The valve is also very rugged.

Valves at present developed for this production method include small signal diodes and tetrodes and a beam power tube. It is expected that the new type of valve will be used in conventional radio, television and special equipment.





Rubber covering of a centrifuge basket being dry-spark tested at a potential of 25,000 volts for homogeneity.

Rubber has been used for lining chemical plant for over forty years; its specialised application — together with that of the newer synthetics—is explained below

RUBBER FOR LININGS AND COATINGS

THE use of rubber and ebonite linings as a protection against both corrosion and abrasion has been a normal part of industrial practice since the 1914-18 war. Linings are applied to storage tanks of all kinds, pickling and plating vats, reaction vessels, road and rail tankers, pumps, valves and pipelines, hoods, ducts and fume stacks. Rubber and ebonite are also used as protective coverings for fans, stirrers, filter parts, plating and centrifuge baskets, and other similar items.

Since the early 'twenties, firms specialising in lining work have amassed not only a great deal of technical knowledge on the subject, but also—and even more important—a vast amount of practical experience. The fact is that no two lining jobs are precisely alike, and no one formula will cover more than a minute fraction of the problems that arise in practice. Chemical linings should in every case, therefore, be tailor-made; and they should be entrusted to a specialist. It is one thing to look up the chemical resistance of rubber in a text-book; but quite another matter to design in each instance the precise compound which will be uniquely suited to the particular situation.

Moreover, the specialist should be given all possible information about the installation—the chemicals to be handled, the purposes for which they will be used, the temperatures of operation, and the presence of sand, crystals or other abrasive material. It is important to know if the linings will be exposed alternately to two or more different chemicals, for sometimes a lining which will withstand (say) an acid or an alkali separately may break down if exposed to frequent alternations between the two. The presence of ingredients in the liquor in trace quantities can have a cumulative effect on the lining, and small traces of contaminants may also have an importance out of all proportion to the minute percentage present. On the other hand, care may have to be taken to ensure that pure liquors are not stained or otherwise contaminated by small traces of compounding ingredients leaching out of the linings.

It is wise also, unless the designer is very sure of his ground, to consult the specialist on the materials and construction of all equipment intended for lining. Often a small modification at the design stage can make the process of lining easier and more efficient, with consequent saving not only in the cost of the original construction, but often in maintenance charges as well.

Properties of Rubber and Ebonite

Of all the lining materials available today, the rubbers are undoubtedly the most versatile. Natural rubber is itself resistant to most of the chemicals commonly used in industry, including hydrochloric acid in any concentration, phosphoric acid up to 85 per cent, sulphuric acid up to 50 per cent, all the alkalis, and most of the salt solutions, dyes and bleaches that are at all widely used.

By varying the compounding ingredients which go into the mix before vulcanisation, it is possible to alter the physical and chemical properties of the product over a remarkably wide range. Thus the hardness can vary from a comparatively soft, almost pure gum with an extremely high resistance to abrasion to a smooth, hard, shiny ebonite which has a higher chemical resistance and is easier to clean, but will not stand up to quite so much abuse in the form of sudden impact or abrasion. Similarly, variations in the amount and nature of the fillers and reinforcing agents used, and of the accelerators, plasticisers and other ingredients added, lead to considerable variations in temperature resistance and resistance to particular chemicals and contaminants.

The choice between rubber and ebonite depends largely on the conditions of service. Ebonite has a somewhat higher chemical resistance than soft rubber, but the difference is not often significant. Of more importance is the fact that ebonite can be polished to a smooth finish, which is invaluable in the food industry, or when dealing with sticky or oily fluids. Ebonite is also less likely to discolour water-white liquors, and it has a lower water absorption.

Where ebonite linings are likely to be exposed to impact hazards as in transport vessels, or to rapid changes of temperature as in open-air storage tanks, the likelihood of cracking can be avoided by sandwiching a flexible layer of soft rubber between the metal and the ebonite. Alternatively, one of the new flexible ebonites can be used. These are made by mixing a proportion of neoprene or butyl rubber with natural rubber or S.B.R. Neither of

these synthetics will combine with large quantities of sulphur in the cure to make a hard ebonite. Instead, they remain largely uncombined and act as a plasticiser in the final product. Flexible ebonites of this sort will give an impact strength of 0·4 ft. lb. (Izod) or even higher, and the neoprene-modified type has a higher abrasion resistance than any other ebonite.

For really high abrasion resistance, however, as required for handling such materials as corrosive slurries or suspended crystals, soft rubber linings are better than ebonite. In fact, the compounds used for this purpose are usually very soft like the anti-abrasive linings of sand and shot-blast hose, grain hose and dredger hose. Such linings are also widely used as protection against abrasion when little or no question of corrosion arises. Typical examples are the coal chutes in power stations which are frequently lined with rubber. Hoppers may be similarly lined, and the rubber lining of ball mills is common practice for ordinary wet grinding as well as for grinding in acid conditions.

Temperature Resistance

Ordinary grades of ebonite begin to soften at about 65 deg. C., and are not usually recommended for continuous use above 70 deg. C. Special compounds, however, can be formulated which will give satisfactory service for long periods at higher temperatures, usually at some sacrifice in impact resistance. Similarly, special rubber compounds can be designed for use up to 100 deg. C., though this is not often desirable. In general, problems of high-temperature operation are more satisfactorily solved by the use of one or other of the synthetic rubbers.

The general-purpose synthetic now known as S.B.R. or styrene-butadiene rubber—a very much improved form of the old war-time GR-S—has approximately the same chemical resistance as natural rubber, whether compounded for use as a soft lining or as an ebonite, with a slight advantage in temperature resistance. More significant is the higher temperature resistance of butyl rubber, which in ordinary compounds can be used continuously at 90 deg. C. and can be specially compounded to withstand anything up to 105 deg. C. or even 110 deg. C. Linings of neoprene have roughly the same temperature range, though their use above 100 deg. C. is rare.

Neither butyl or neoprene rubber will produce a true ebonite, so that these synthetics are available only as soft linings. The nitrile rubbers, however, do yield an ebonite with a temperature resistance considerably above that of natural rubber or S.B.R. ebonites. Nitrile ebonites will give satisfactory service up to 110 deg. C., and cases are on record of their successful employment at temperatures rising intermittently as high as 140 deg. C. Their chief drawback is that they are particularly difficult to process, and apt to be expensive in consequence.

Chemical Resistance of Synthetic Linings

There are two main limitations to the chemical resistance of natural rubber: it cannot be used satisfactorily in contact with mineral oils and solvents, or with strong oxidising agents, including nitric acid, chromic acid and concentrated sulphuric acid. It is in overcoming these limitations and so extending the range of applications for rubber linings generally that the synthetics have their chief value.

Neoprene, for instance, was first developed before the war as a rubber which would not lose its essential properties in contact with mineral oils. It is normally used for chemical linings in conditions where there may be traces of oil present with other chemicals, though nitrile rubber is also available for this purpose. It is also more resistant to ozone, sunlight and weathering generally than natural rubber, and is sometimes employed on sites where equipment is likely to be exposed for long periods in the open air.

Butyl rubber also has good weather resistance, and because of its very low gas permeability it is frequently used for gas-liquor phases where its high-temperature resistance is an added advantage. It can be used with dilute nitric acid and it is being increasingly employed for animal and vegetable oils and fatty acids.

For the strong oxidising acids a comparatively recent material is chlorosulphonated polyethylene, which withstands sulphuric acid up to 95 per cent and nitric acid up to 70 per cent at room temperatures, 50 per cent chromic acid up to 50 deg. C., and 85 per cent phosphoric acid up to 90 deg. C., though possibly with some staining at the higher concentrations. So far this synthetic has not been very much used for plant linings in the U.K., but its increasing employment for chemical hose delivering hot acids to plating, pickling and dyeing vats suggests that it may well come to have wider use for linings also in these industries.

In Table 1 an attempt has been made to set out systematically the resistance of various forms of lining to different chemicals. Such a table, however, can never be either final or exhaustive. Chemical resistance is rarely a simple matter of yes or no. It is rather a question of degree. Difficult conditions can sometimes be met by accepting a slight sacrifice in physical properties, or a somewhat shorter life than would normally be expected. For plating and pickling tanks a common practice now is to build a brick shield inside the lining, which protects the rubber not only from mechanical damage, but also from the full temperature of the liquors in the vat.

Design of Vessels

Almost equally important with the choice of lining is the design of the vessel to be lined. Steel is usually preferred on account of strength, low cost and ease of fabri-

Filter press plates coated with ebonite.

Rubber-covered agitators for chemical use.

TABLE 1. Chemical resistance of natural and synthetic rubber and ebonite linings

	Natural Rubber and S.B.R.		Nitrile		Butyl Rubber	Neoprene	Chlorosulphonated Polyethylene
	Soft	Ebonite	Soft	Ebonite			
Acids							
Acetic	X	S	L	S	L	S	S
Chlorine water	S	S	L	S	L	X	S
Chromic 50%	X	X	X	X	X	X	L
Hydrochloric	S	S	L	S	S	L	S
Hydrocyanic	S	S	S	S	S	S	S
Hydrofluoric	S	S	L	L	S	L	S
Nitric 8%	X	X	X	X	S	X	S
Nitric 20%	X	X	X	X	L	X	S
Nitric 40%	X	X	X	X	X	X	S
Phosphoric 80%	S	S	L	S	S	S	S
Sulphuric 20%	S	S	L	S	S	S	S
Sulphuric 25%	S	S	L	S	S	S	S
Sulphuric 50%	S	S	L	S	S	L	S
Inorganic Salts and Alkalis							
Ammonia 25%	S	S	S	S	S	S	S
Ammonium hydroxide	S	S	S	S	S	L	S
Ferric chloride	L	S	S	S	S	L	S
Silver nitrate	L	S	L	S	S	S	—
Zinc chloride	S	S	S	S	S	S	S
Organic Materials							
Acetone	S	S	X	S	S	X	X
Alcohols	S	S	S	S	S	L	S
Detergents	S	S	S	S	S	S	S
Ethers	X	X	S	X	L	L	S
Ethylene glycol	S	S	S	S	S	S	S
Methyl chloride	X	X	X	X	L	X	X
Mineral oils	X	L	S	S	X	L	S
Phenol	L	S	X	S	L	X	X
Soap solution	S	S	S	S	S	S	S
Vegetable oils	X	L	S	S	S	L	—

S—satisfactory results likely. X—not recommended. L—limited application

These indications provide a guide only. They refer to chemical resistance at room temperatures, but do not necessarily apply to higher temperatures, especially for acids. Also, rapid alternations of temperature or chemicals or abrasion and mechanical damage all affect the choice of lining.

cation; but other metals can be used such as cast iron, aluminium or brass, and occasionally wooden vats are lined. Mild-steel tanks should conform to the relevant specifications, particularly B.S. 2594: 1955, and for pressure vessels B.S. 1500: 1949. They should, if possible, be of welded construction, the welding continuous, free from porosity, cracks, crevices or any places where air or foreign matter could be trapped. Single or double V-butt joints are preferred to lap joints, but in any case all welds on the surface to be covered should preferably be ground flush and smooth, blending into the adjoining surface.

Riveting is not recommended. If it cannot be avoided, the rivets should be flat, tight-fitting and countersunk flush with the adjacent surface, with no undercutting or crevices round the rivet heads.

All sharp corners and angles should be avoided. Inlets and outlets should be flanged or have pads with studs. Particular care is required where vessels have internal strengthening ribs, struts, tie-bars, cleats, baffles, weirs or other projections. If necessary, fillet welds should be used on corners, and all angles smoothed to a radius of not less than $\frac{1}{4}$ in.

If castings have to be used, they should be of close-grained grey iron, free from porosity or surface blowholes. On no account should flaws be filled in with iron cement: they must be thoroughly ground out and plugged with metal with a melting point of at least 150 deg. C., well hammered down so that no air is trapped underneath. Alternatively, a filling of uncured rubber or ebonite can be used.

All surfaces to be covered, whether of steel or cast iron, should be free from weld spatter, burrs, porous spots, depressions or pits. They should be left free from grease and unpainted, and they should not be galvanised. In the last instance, however, it is possible if a galvanised tank is in good condition to remove the zinc by shot-blasting, but there is always a possibility of some traces remaining and the resultant bond being reduced in consequence below optimum strength.

It greatly assists the process of lining of closed tanks if these are constructed with a detachable flanged end, giving easier access for cleaning and lining, and for the circulation of steam or hot air in vulcanisation. Very long vessels can often be made in two or more sections which can be separately lined, and then assembled on site. This form of construction also greatly facilitates inspection and cleaning and any repairs that may be required, including stripping and re-lining.

If one-piece structure is unavoidable, manholes of at least 18 in. diameter should be provided in accordance with B.S. 2594: 1955. If there is only one manhole, an outlet branch for a fume-extraction pipe will be required, and it should be situated as far as possible from the manhole to facilitate maximum circulation.

Methods of Lining

The lining process consists first in thoroughly cleaning the surfaces of the metal, usually by sweating in steam followed by shot-blasting. Bonding agents are then applied, and the unvulcanised sheets of calendered rubber laid on and carefully rolled down by hand over the whole surface of contact. Special precautions must be taken at the seams

between one sheet and another, and round all angles and corners, to ensure that no air is trapped anywhere under the rubber or it will expand during vulcanisation and leave a blister.

Heated iron tools are used to press the rubber sheet into close contact with the metal and to force out all air. At the seams the heat and pressure weld the sheets into a homogeneous lining, and, before vulcanising, the quality of the workmanship is tested by a dry spark test. A flexible wire at a high potential is trailed over the exposed surface of the rubber. If there is any flaw in the lining, a bright white spark is seen where the electricity passes through the rubber to the metal. This test is repeated after vulcanisation to ensure that the job is perfectly sound when it leaves the works.

For preference the vulcanising is done by saturated steam or hot air at temperatures between 110 and 153 deg. C. and pressures of 40-60 p.s.i. in a special vulcanising pan or autoclave. Plant-lining firms have large pans for the purpose 20-25 ft. in length and up to 15 ft. in diameter. The vulcanising process gives the rubber elasticity, resistance to abrasion and chemical attack and bonds it firmly to the metal surface. The bond is not just a physical adhesion, but a true chemical bond, as strong as, if not stronger than, the rubber or ebonite itself. There is, therefore, no question of the lining coming away under reduced pressure, and it is eminently suited for working under vacuum conditions.

Rubber and ebonite are equally suitable for high-pressure work; for here the ultimate strength is the strength of the steel vessel itself, while a properly bonded lining will resist any tendency to blister or peel off when the pressure is released.

Components that are too large to be transported or to go into a vulcanising chamber can be lined on site, and vulcanised by introducing hot air, hot water or low-pressure steam into the vessel itself. Tanks up to a capacity of 2,000,000 gallons have been lined in this way; but it remains a highly specialised job, and each particular case calls for detailed individual treatment.

Concrete vessels can be lined with unvulcanised rubber sheeting attached by adhesives and cured on site with hot air, hot water or steam. Alternatively, a layer of self-vulcanising rubber can be applied.

Large stirrers, fans, centrifuge baskets, etc., are covered with unvulcanised sheet rolled on carefully by hand—a difficult and highly skilled job when intricate curved surfaces have to be covered—and cured in a suitably sized autoclave. In this way the maximum bond strength either for soft coverings or for ebonite is ensured. Smaller items such as might be used in small-scale pickling or plating can be covered by dipping in a specially compounded latex and then vulcanising.

Steel pipes can be lined with either rubber or ebonite by drawing a tube of the uncured compound through them, attaching to the flange coverings, and vulcanising under pressure. The largest sizes, however, are big enough to have linings hand rolled. Rubber-lined pipework is frequently used for bringing cooling water either from the sea or from freshwater sources to power stations and other industrial installations. If laid underground, the pipes can be covered also on the outside as a protection against soil corrosion.

Pipes for lining, together with bends, tees, crosses, etc., should have flanged or plain ends, not threads, and allowance should be made for the thickness of the lining when specifying the bore. Similarly, allowances should be made in calculating the length of pipework for the thickness of the lining carried over the flange plus the thickness of a flange washer.

Pumps, valves and cocks can be lined with either soft rubber or ebonite, but ebonite has the advantage of being easy to machine to close tolerances after vulcanisation. In the smaller sizes, of course, fabricated ebonite pumps, valves, pipes and fitments are available, and, provided they are adequately supported and not required to work at high temperatures, they have been found to have a remarkably long life. Installations that have given continuous and satisfactory service for fifty years and more are not uncommon.

This article has been contributed by a special correspondent of the Plant Lining Group of the Federation of British Rubber and Allied Manufacturers. Firms comprising the group are: B.T.R. Industries Ltd., Dexine Rubber Co. Ltd., Dunlop Rubber Co. Ltd., Nordac Ltd., Redferns (Bredbury) Ltd. and St. Helens Cable & Rubber Co. Ltd.

EARLY RESPONSE TO BRITISH DESIGN SHOW

LEADERS from various fields of industry have been quick to respond to the news released recently of the first ENGINEERING MATERIALS AND DESIGN Exhibition which is to take place in London in the New Year. Many readers of this journal have already shown by their enthusiasm how welcome is the decision at last to hold an exhibition, run concurrently with a technical conference, appealing specifically to engineering designers and others concerned with the correct selection and application of materials and components.

The exhibition—to be held at Earls Court from February 22-26—is being organised by Industrial & Trade Fairs Ltd., an associate company of the publishers of ENGINEERING MATERIALS AND DESIGN. It will be the first event of its kind ever to be sponsored in this country with the design section of modern engineering industry primarily in mind. Rather than being concerned with the products of any one industry its emphasis will be on the materials and components that are used for various applications in every type of modern industry, from motor cars to missiles, from washing machines to wind-tunnels. An important aspect of the exhibits will be the growing significance of "cross-fertilisation" of ideas in present-day design, indicating ways in which applications in one industry may assist designers in another.

Exhibits are expected to embrace a wide variety of materials, including metals, plastics, rubber, ceramics, etc., while there will be an opportunity of examining first hand many of the new components that manufacturers have recently introduced.

At the same time, the occasion will provide common ground on which designers will be able to discuss personally with suppliers' representatives specific technical problems relating to their products.

During the period of the exhibition, there will be a technical conference held under the same roof at Earls Court. The papers to be read and discussed at this will fall broadly under three headings: "Materials", including specifically beryllium, stainless steels, magnesium, rubber, high-temperature plastics, etc.; "Components", including seals, castings, pumps, units used in high-pressure hydraulics and fluid power, etc.; and "Design", which will deal with, among other topics, the establishment and maintenance of standards, developments in photo-elasticity, trends in production, design, safety design and appearance design.

Fuller details of the conference will be published in next month's issue.

HIGH ALLOYS OF CHROMIUM, COBALT, COLUMBIUM, MOLYBDENUM AND VANADIUM

To find materials capable of maintaining specific mechanical properties at high temperatures, detailed studies have been made of the effect of alloying certain metals. Some of the properties obtained are discussed here

by H. R. OGDEN*

CHROMIUM, cobalt, columbium, molybdenum and vanadium can be classed as jet-age metals. Interest in these elements as bases for high-temperature alloys has stemmed directly from the need for constructional materials that have useful properties at temperatures encountered in gas turbines. The development of cobalt-base alloys, the considerable amount of research that has been done on molybdenum-base alloys, and the current interest in the development of chromium-, columbium- and vanadium-base alloys can be attributed to the need for higher operating temperatures.

Sheet materials having high strengths at elevated temperatures are required, dictating that, in addition to having useful strength properties, the materials must be capable of being fabricated to sheet and formed into parts. One other very important property is the oxidation resistance of these metals at service temperatures. Of the five, only cobalt and chromium alloys have sufficient oxidation resistance to be used without protection at elevated temperatures.

In Fig. 1, where the tensile strengths in the temperature range of 1,000-2,000 deg. F. are shown, it can be seen that the general relationship of strength to melting point holds true. Molybdenum, with the highest melting point, has the highest elevated-temperature strength and cobalt the lowest. Chromium and vanadium, which have relatively close melting points, are fairly close in strength levels at 2,000 deg. F., while the strength of columbium is between their strengths and the strength of molybdenum.

Modulus of elasticity is an important property in the designing of parts for compression and buckling applications. In such applications a high modulus is desirable, and in this property, as in strength, molybdenum is outstanding. Fig. 3 shows the variations of modulus with temperature for four of the metals. For vanadium, only room-temperature modulus is available.

One other property which is of prime importance in consideration of a metal for sheet applications is its low temperature ductility, both from the viewpoint of sheet-forming operations and design considerations. Chromium, molybdenum and columbium undergo a ductile-to-brittle transition at temperatures of: chromium, 500 deg. F.; molybdenum, room temperature; and columbium, −180 deg. F. Similar data for cobalt and vanadium are not available. However, it can be assumed that the transition temperature of vanadium will be considerably below room temperature based on its similarity to columbium and tantalum, both of which have very low transition temperatures (see Fig. 5).

The ductility of chromium at room temperature must be considered borderline. Only a few tests of many conducted have shown room-temperature tensile ductility in pure chromium. Also, all known alloy additions and impurities added to chromium decrease its ductility and raise the ductile-to-brittle transition temperature. Chromium sheet can be prepared by warm or hot rolling, but its usefulness is questionable.

Molybdenum has a ductile-to-brittle transition near room temperature. However, if fabricated properly to sheet, it has very good ductility. Proper fabrication includes warm working (or, as it is sometimes called, hot-cold working) at temperatures well below the recrystallisation temperature to produce a fibrous grain structure. In this condition, thin sheets (0·020 in. thick or less) of molybdenum can be bent through 180 deg. at room temperature. Heavier gauges can be bent at slightly elevated temperatures (200-1,000 deg. F.) with no difficulties. Similarly, thin gauges can be spun at room temperatures and slightly thicker gauges can be spun at 200-400 deg. F. Deep drawing of all gauges can be done warm, usually in preheated dies, at temperatures of 200-1,000 deg. F., depending on the thickness of the sheet.

Vanadium and columbium are both very ductile materials at room temperature even in the recrystallised condition. Both can be cold rolled at least as much as 90

* *Consultant, non-ferrous physical metallurgy division, Battelle Memorial Institute, Ohio.*

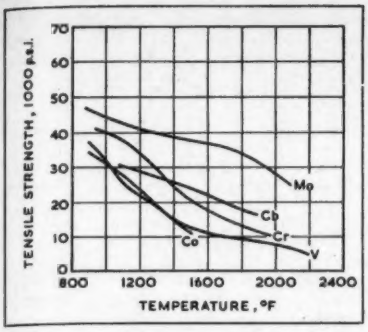


Fig. 1. Tensile strength of the high-temperature metals in the range of 1,000-2,000 deg. F.

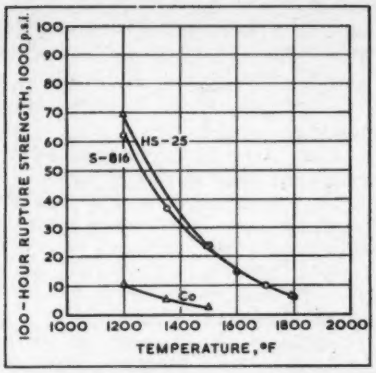


Fig. 2. 100-hour stress rupture strengths of cobalt-base alloys.

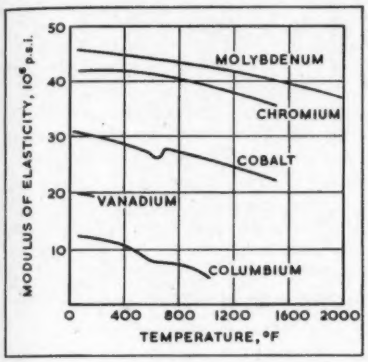


Fig. 3. Effect of temperature on the modulus of elasticity of high-temperature metals.

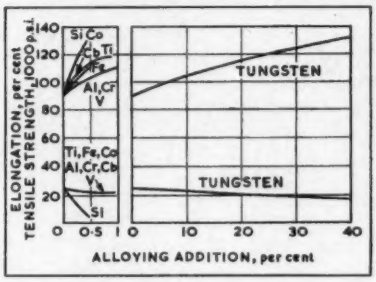


Fig. 4. Effect of alloying conditions on the tensile properties of molybdenum.

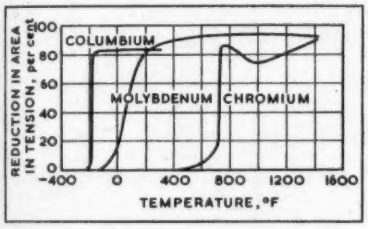


Fig. 5. Effect of temperature on the ductility of chromium, molybdenum and columbium.

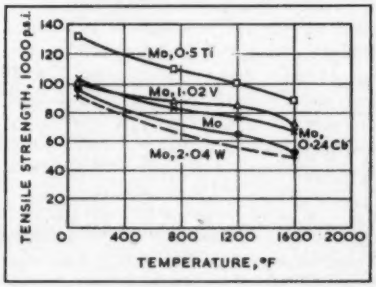


Fig. 6. Effect of test temperatures on the tensile strength of molybdenum alloys in the hot-cold-worked and stress-relieved condition.

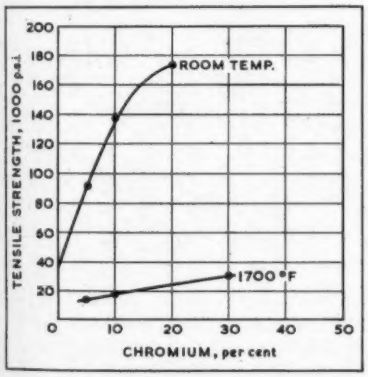


Fig. 7. Effect of chromium on the tensile strength of cobalt at room temperature and 1,700 deg. F.

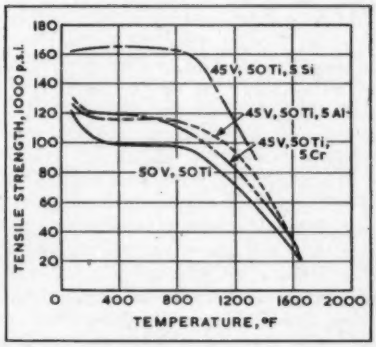


Fig. 8. Effect of temperature on the tensile strength of some vanadium-titanium alloys.

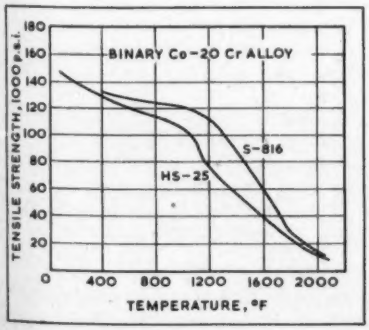


Fig. 9. Effect of temperature on the tensile strength of wrought cobalt-base alloys.

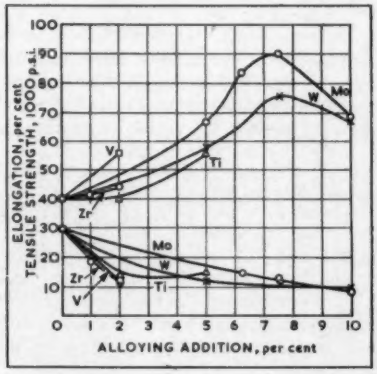


Fig. 10. Effect of alloying conditions on the room temperature tensile properties of columbium.

per cent with no intermediate anneals, and can be bent, spun and deep drawn at room temperature.

COBALT-BASE ALLOYS—Little data are available on the formability of pure cobalt. It has excellent tensile ductility at room temperature and presumably could be bent and otherwise formed into parts without heating.

Early cobalt-base alloys were developed as casting alloys. To obtain sheet alloys many composition modifications have been made, including several examples listed in Table 1. The chief modification for producing wrought alloys has been to lower the cobalt content and increase the nickel content.

Cast alloys were suitable for the production of small parts, particularly turbine buckets and nozzles, by the investment casting process. Sound castings within good tolerances could be made by this method.

The effect of chromium on the room temperature and 1,700 deg. F. tensile strength of cobalt is shown in Fig. 7. The strength levels obtained in binary cobalt-chromium alloys containing 20-30 per cent chromium are about the same at room temperature and 1,700 deg. F. as are obtained in the complex cobalt-base alloys such as L-605 (HS-25) or S-816 (see Fig. 9).

The important effect of alloying in increasing the elevated temperature properties of cobalt is illustrated in Fig. 2, where the stress-to-produce rupture in 100 hours is shown for unalloyed cobalt and the two wrought cobalt-base alloys. If a criterion of 10,000 p.s.i. for the 100-hour rupture strength is used to define the useful strength, it can be seen that the maximum use temperature has been increased from 1,200 deg. F. for cobalt to 1,700 deg. F. for the wrought cobalt-base alloys.

The cobalt-base alloys HS-25 (L-605) and S-816, have excellent ductility at room temperature. They can be cold-rolled, bent to various shapes, and otherwise formed into parts at room temperature. In general, the formability of these alloys is very similar to stainless steel, except that more force is required during forming.

MOLYBDENUM-BASE ALLOYS—Molybdenum has a rather small tolerance for alloying elements. With the exception of tungsten, the limit of alloying elements that can be added to molybdenum is of the order of 1 per cent before embrittlement occurs. However, these small additions have a profound effect on the properties of molybdenum, particularly at high temperatures.

The effects of various elements on room-temperature properties of molybdenum are shown in Fig. 4, where it can be seen that small amounts of many different elements have a significant strengthening effect. The strengthening effect of these small additions is maintained at elevated temperatures as shown in Fig. 6 for a few of the alloys.

As for unalloyed molybdenum, molybdenum alloys should be warm worked to produce a fibrous structure. A stress-relief anneal, usually ½-1 hour at 1,800-2,000 deg. F., is used to relieve residual stresses resulting from fabrication. In the stress-relieved condition, the strength levels are significantly higher than in the recrystallised condition at temperatures up to the temperature at which recrystallisation occurs during service or testing.

CHROMIUM-BASE ALLOYS—Chromium metal, because of its borderline ductility at room temperature, has little tolerance for alloying additions. Almost any impurity or intentional addition to chromium embrittles it.

The three systems Cr-Fe, Cr-Ni and Cr-Co appear to have the best potential for producing chromium-rich alloys, particular examples for hot-rolling to sheet being 76 per cent Cr for Cr-Fe, 63 per cent for Cr-Ni and 45 per cent for Cr-Co.

TABLE 1. Compositions of wrought cobalt-base alloys

Alloy Designation	Per cent								
	Co	Cr	Ni	W	Si	Mn	Fe	Mo	Cb
HS-25, L-605	51	20	10	15	1·0	1·5	1	—	—
S-816	44	20	20	4	0·7	1·5	3	4	4
V-36	42	25	20	2	0·4	1·0	3	4	2
N-155, HS-95	20	21	20	2·5	0·5	1·5	30	3	1

TABLE 2. Stress-rupture properties of Cr-Fe base alloys at 1,500 deg. F.

Alloy Composition %	Stress, p.s.i.	Rupture Time, hr.	Elong., %	Reference
60Cr-40Fe	20,000	0·15	15	24
60Cr-40Fe	15,000	0·28	14	24
62Cr-26·5Fe-8Mo-3·5Ti	28,000	161	20·7	25
62Cr-26·5Fe-8Mo-3·5Ti	23,000	450	22·8	25

TABLE 3. Stress-rupture properties of columbium and a Cb-10Ti alloy at 1,800°F. and 2,000°F.

Temp. °F.	Columbium		Cb-10Ti	
	Stress, p.s.i.	Rupture Time, hr.	Stress, p.s.i.	Rupture Time, hr.
1,800	—	—	22,500	4·7
1,800	17,500	0·5	17,500	17·0
1,800	15,500	43·0	15,000	33·0
1,800	14,000	>240	10,000	139·8
2,000	14,800	~0·1	16,700	~0·1

TABLE 4. Present and future temperature ranges of materials

Alloy Base	Present Temp. Limit, °F.	Poss. Future Temp. Limit, °F.
Tungsten and tantalum	—	2,700–3,500
Molybdenum	2,200	2,200–3,000
Columbium	1,900	2,000–2,500
Chromium	1,800	2,000
Cobalt	1,800	1,850
Nickel	1,800	1,850
Iron	1,600	1,700
Vanadium	1,300	—
Titanium	900	1,200

Although the data obtained so far are limited, it is believed that chromium-base alloys will be useful at temperatures up to 1,800-1,900 deg. F. in structural applications.

VANADIUM-BASE ALLOYS—An extensive research on the properties of vanadium-base alloys was conducted a few years ago at Armour Research Foundation. The results of that work showed that only in the vanadium-titanium system could fabricable alloys be obtained beyond 10 per cent alloying addition. It appeared that the vanadium-titanium system offered the best potential for producing high-temperature alloys, and considerable research was conducted on this system.

Additions of a third element to the V-Ti alloys provide significant improvements in the tensile strength as shown in Fig. 8 for several additions to the 50V-50Ti base. This strength advantage is maintained at temperatures up to about 1,200 deg. F. However, the vanadium-base alloys all lose strength rapidly at temperatures in the region of 1,000 deg. F.

COLUMBIUM-BASE ALLOYS—Although currently there is considerable interest in columbium-base alloys, only

TABLE 5. Properties of the high-temperature metals

	Cobalt	Chromium	Vanadium	Columbium	Molybdenum
Melting point, °F.	2,720	3,400	3,450	4,380	4,750
Density, lb./cu. in.	0·320	0·260	0·217	0·310	0·369
Recrystallisation temperature, °F.	725	1,500	1,550	2,200	2,300
Crystal structure	HCP/FCC	BCC	BCC	BCC	BCC
Transformation temperature, °F.	783	—	—	—	—
Electrical resistivity, microhm-cm	5·6	13·0	25·0	13·1	5·8
Thermal conductivity, cal./(sec.) (cm.) (°C.)	0·165	0·16	0·07	—	0·32
Coefficient of linear thermal expansion per °C. $\times 10^{-6}$	14·2	6·2	8·3	7·1	5·1
Specific heat, cal./gm./°C.	0·100	0·11	0·127	0·065	0·061

limited data are available on the effects of alloying elements on the mechanical properties of columbium. Current interest stems from the potential strength of columbium at elevated temperatures based on its high melting point combined with its excellent fabricability.

Alloying additions to columbium appear to have a relatively mild strengthening effect at least as compared to the effects of alloying additions on molybdenum. However, significant strength improvments can be obtained at room temperature by the additions of other transition elements as shown in Fig. 10. Vanadium, molybdenum, tungsten and titanium all provide significant improvements in the tensile strength of columbium with some sacrifice in tensile ductility.

Fewer data are available on the elevated temperature strengths of columbium-base alloys, and these are shown in Table 3.

It is obvious that the limited data on columbium-base alloys are not sufficient to estimate the potential usefulness of these alloys. Much more research must be done before the full potentialities of columbium-base alloys are known.

This is an abridged version of an article published by the American Society for Metals as a special publication entitled "Sheet Materials for High Temperature Service".

TRAINING ENGINEERING DESIGNERS IN 1960

The following technical colleges in the U.K. have announced details of various courses on engineering design which are to be held during the coming session, 1959/60. In most cases, classes begin well before the beginning of October, and early application for admission should be made.

ESSEX

S.E. Essex Technical College and School of Art, Longbridge Road, Dagenham. Subject: "Technical Illustration". Three-year evening course. City and Guilds Intermediate and Final examinations.

Mid-Essex Technical College and School of Art, Market Road, Chelmsford. Subject: "Design—Art in Relation to Technology". Three-year evening course. Intended mainly for section leaders of design teams, engineering designers and others in drawing offices and research departments of local industries.

HERTS

Hatfield Technical College, Roe Green, Hatfield. Subject: "Designing for Production". Two days a week for twelve weeks. Intended to introduce students with industrial experience and Ordinary N.C. to design problems in relation to modern drawing office practice.

NOTTS

Nottingham & District Technical College, Burton Street, Nottingham. Subject: "Mechanical Engineering Design". One-year evening course. For students with H.N.C. or degree in mechanical engineering.

LANCS

Liverpool College of Technology, Byrom Street, Liverpool 3. Subject: "Design and Stress Analysis". One year full-time course, for students with H.N.C. in Mechanical Engineering. (Most students are sponsored by the U.K.A.E.A. at Risley, but others are accepted). Subject: "Design of Heat Exchange Equipment". Post advanced part-time evening course at Risley in collaboration with U.K.A.E.A.

Manchester College of Science and Technology, Manchester 1. Subject: "Machine Tool Design". Two-year full time course. Intended for persons with extensive industrial experience and with qualifications at least equivalent to Higher N.C. in Mechanical Engineering. (The possibility of establishing a diploma course in Industrial Design (Engineering) is at present being considered.)

Peel Park Technical College, School of Art and Industrial Design, Salford 5. Subject: "Industrial Design (Appearance Design and Ergonomics)". Basic course occupies one evening/afternoon a week for twenty-five weeks. Advanced course occupies one afternoon a week for the same period. Subject: "Technical Illustration". Basic and advanced courses. One evening a week for one year.

STAFFS

Wolverhampton & Staffordshire College of Technology, Wulfruna Street, Wolverhampton. Subject: "Industrial Design". (1) Part-time day release course (one day and one evening a week) for senior students from industry, preferably with H.N.C. in engineering and good industrial experience. (2) Evening classes (one a week) for younger students from industry. (3) One lecture a week on the subject to Diploma in Technology engineering students of the college. (4) A junior course (one half day a week) for students of 15-16 years old of the Wulfrun College of Further Education.

YORKS

Huddersfield College of Technology. Subject: "Standardisation in Engineering". Course of seven lectures.

Fig. 1. Typical fatigue failure of whitemetal bearing.

HOW TO CHOOSE MATERIALS FOR BEARING SURFACES

by P. G. FORRESTER, M.Sc., F.I.M.*

Friction and wear—the results of two surfaces sliding together under load—are common to every mechanism. Here is indicated how suitable materials may be selected to minimise the effects of both these factors

EVERY bearing has two surfaces and the character of each of these is of equal importance. Generally it is convenient to use a conventional structural material such as steel as one surface and to have a specially-chosen "bearing material" as the other.

The most suitable type of material depends very greatly on the application. Soft rubber, lead and diamond are materials with very different properties, but each is a suitable bearing material in certain conditions. In this article, bearing materials are separated into three types, according to whether they are to be used for full lubrication, sparse lubrication or no lubrication (dry) conditions.

Fully-lubricated Bearings

In a journal bearing supplied with oil, the oil is drawn into the wedge formed by the clearance space and develops a hydrodynamic pressure, which tends to prevent actual contact between bearing and journal surfaces. In thrust bearings, a similar wedge-action may be obtained either by using tilting pads (Michell thrust bearings) or by specially-designed oil-grooves. If complete separation can be maintained, no wear occurs and friction is small at moderate speeds. Such complete fluid lubrication is achievable, but the design requirements it imposes may conflict with other design restrictions such as cost, size and complexity. In most fully-lubricated bearings, the surface materials must be able to cope with departures from fluid lubrication. Two main types of departures have to be considered:

1. TRANSIENT CONDITIONS OF SPEED AND LOAD—When starting or stopping, or under certain load/speed conditions, insufficient pressure is built up to separate the surfaces. It is then a major advantage to have a soft material for one surface. A soft material conforms to the profile of the harder surface and so assists in the maintenance of a thin oil film of high load carrying capacity. Thus, with soft materials, a fluid film can be maintained where, with harder materials, it would break down. Furthermore, a soft material confines the damage to one surface which then tends to be moulded again by the harder surface. If both surfaces are of the same hardness, a ridge on one tears a groove in the other, so the amount of damage rapidly builds up.

2. SOLID MATTER IN THE OIL—It is difficult, and often practically impossible, to ensure that the oil supplied to a bearing is clean. In particular, in I.C. engines, where the same oil lubricates the cylinder walls, etc., as well as the bearing, a fair amount of contamination with wear debris and other dirt is the principal cause of wear of the bearings, the crankpins being abraded by dirt embedded in the bearing surfaces. The effect of bearing material on the rate of crankpin wear has been investigated in detail. Tests extending over a number of years have been carried out on a number of types of vehicles under normal operating conditions and also under specially arduous service conditions. The procedure was to use the four (or six) big-ends as four (or six) test heads, always comparing the wear with an experimental material with that of a reference whitemetal bearing, and using statistical techniques to eliminate errors due to big-end position, etc.

The mean results of scores of such tests are shown in Table 1. It will be seen that there is a broad correlation with hardness, the softer materials giving less wear. While a soft bearing material can reduce the damage done by abrasive particles, it cannot prevent it altogether. The importance of oil cleanliness in fluid lubricated bearings cannot be too much stressed.

It is also of advantage for the bearing metal to have a low melting-point, or contain a low-melting constituent. In conditions of distress, local high pressures, which might otherwise result in seizure, can then be relieved by local melting.

* *Chief metallurgist, Glacier Metal Co. Ltd.*

Thus, soft materials with a low melting-point constituent minimise wear and reduce the risk of seizure under conditions of distress. However, it is the duty of a bearing to support a load without mechanical breakdown and strength properties in the material are therefore important. In particular, where alternating loads are applied, the material must be able to withstand them without fatigue failure, of which Fig. 1 is a typical example. Since soft low melting-point materials are generally weak, it is necessary to seek an appropriate compromise between softness and strength. To some extent, we can get the best of both worlds by using thin layers of soft material with a stronger backing. Fig. 2 shows the effect of lining thickness on the fatigue load which whitemetal lined steel-backed bearings can carry, while Fig. 3 shows a similar relationship for a thin layer of lead-tin on steel-backed copper-lead (tri-metal bearings). The actual load figures relate to a particular fatigue test machine, and are therefore relative, not absolute, values.

A further important requirement is that the material must not be liable to chemical attack by the lubricant. Mineral oils tend to oxidise at high temperatures and form acidic products. The development of such acids can be prevented or retarded by the use of inhibitors, but certain oils do nevertheless become acidic in use. These organic acids attack some metals, particularly lead, and if a plain copper-lead bearing is used with an acidic oil, the lead is leached out, weakening the bearing and probably causing failure. An example of failure due to this type of corrosion is given in Fig. 4(a).

Small amounts of tin or indium in the lead prevent such attack. Accordingly, it is common practice to coat copper-lead bearings with a thin overlay of lead-tin or lead-indium alloy. This layer is itself resistant to corrosion, and even if it wears away, sufficient tin or indium will generally have diffused into the lead phase of the copper-lead to prevent attack. Such overlays also reduce the rate of crankshaft wear to approximately that of whitemetal. (Naturally, this only applies so long as this overlay remains, which may be 3,000 hr. or more of normal operation.)

Fluid-lubricated Bearings

With these considerations in mind, we can pass to a consideration of the materials commercially available for high duty bearings operating under good lubrication conditions. In Table 2, the qualities of these materials are summarised. In each case, the lining material is assumed to be bonded uniformly and strongly to a steel backing, which provides the necessary rigidity and increases the effective strength of the lining.

TABLE 1. Results of tests to determine rate of crankpin wear with various materials*

Material (composition %)	Wear†	Hardness (V.P.N.)
Whitemetal	1·0	25
70/30 copper-lead	2·2	36
55/45 copper-lead	1·7	21
90/10 lead-tin	0·9	10
Tin	0·9	6
79/20/1 aluminium-tin-copper	1·6	35
XB-80-S aluminium alloy	2·2	50

* By Glacier Metal Co. Ltd. † Whitemetal = 1.

The figures obtained for fatigue strength were obtained on a specially-designed bearing test machine and are strictly comparable. The conditions imposed by the machine are deliberately rather severe and, under more favourable conditions, all the materials can carry higher fatigue loads than those indicated.

Hence the following can be deduced:

1. For static loads, tin base whitemetal is generally to be preferred, though lead base and intermediate alloys are only marginally inferior. In rare cases, with very high loads or high ambient temperature, a stronger material will be necessary.

2. For alternating loads, whitemetals are to be preferred up to the limit of their load-carrying capacity.

3. For loads beyond the capacity of whitemetal, overlay bearings are best, provided that their load-carrying capacity is not exceeded and *provided the overlay remains.* In practice, there is always some amount of overlay removed by abrasives in the oil, in which case the wear and corrosive behaviour are then of copper-lead. For this reason, aluminium 20 per cent tin alloys may sometimes be preferred.

4. For loads beyond the capacity of overlays on copper-lead, the two alternatives are aluminium-tin or lead-bronze. Of these, the balance of advantages lies with aluminium-tin.

Typical microstructures of some of the alloys mentioned above are shown in Fig. 4(a), (b) and (c).

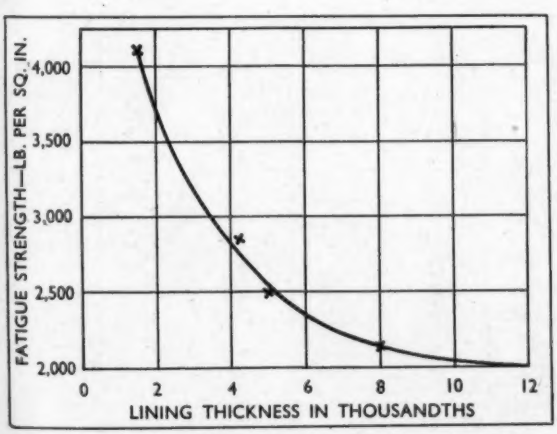


Fig. 2. Effect of lining thickness on fatigue strength of whitemetal-on-steel bearing.[1]

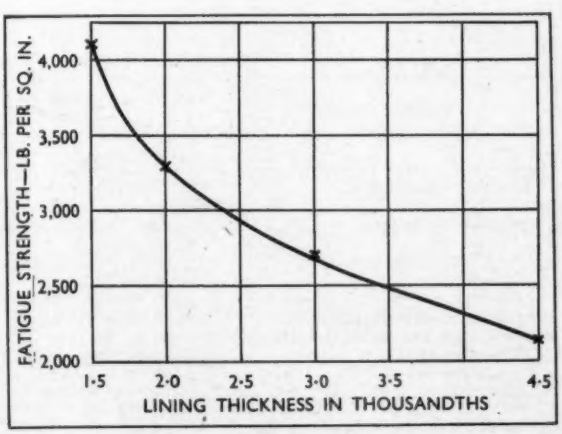


Fig. 3. Effect of lining thickness on fatigue strength of overlay of lead-tin on copper-lead.[1]

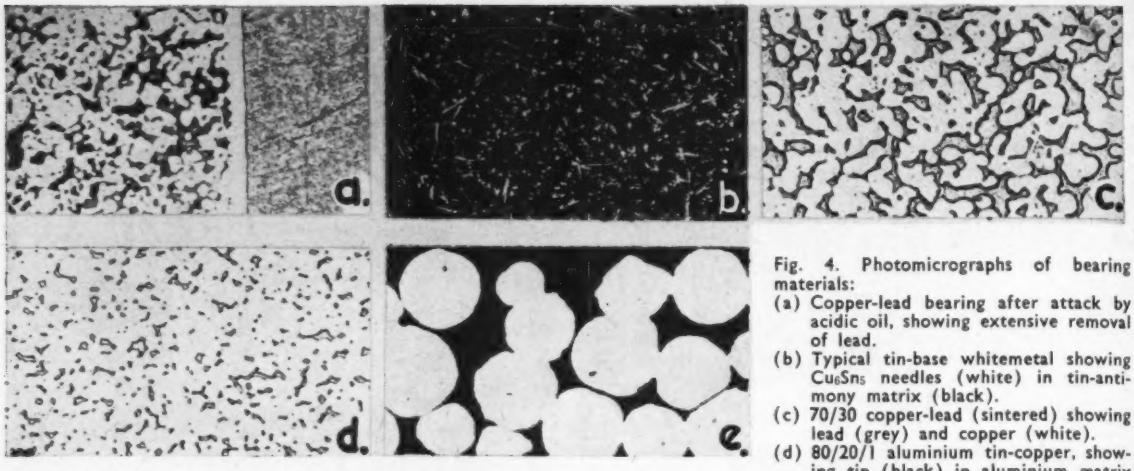


Fig. 4. Photomicrographs of bearing materials:
(a) Copper-lead bearing after attack by acidic oil, showing extensive removal of lead.
(b) Typical tin-base whitemetal showing Cu_6Sn_5 needles (white) in tin-antimony matrix (black).
(c) 70/30 copper-lead (sintered) showing lead (grey) and copper (white).
(d) 80/20/1 aluminium tin-copper, showing tin (black) in aluminium matrix (white).
(e) Glacier D.U. bearing, showing bronze matrix (white) filled with lead-containing p.t.f.e. (black).

Partly-lubricated Bearings

This description covers a wide field of bearing applications in which a fluid film is absent for a considerable proportion of the operating time. This may be because of the character of the movement and/or loading or simply may be because a continuous supply of oil or grease cannot be relied on. An example of the first kind of application is the small-end of I.C. engines, in which a high load is combined with an oscillating movement giving little opportunity for a hydrodynamic oil film to be maintained.

Little reliable test information is available about these types of bearings, probably because of the extreme difficulty of reproducing controlled "poor lubrication" conditions. Accordingly, it is only possible to give the results of general experience with some possible rationalisation.

WHITEMETAL—Useful for light to moderate loads and moderately good lubrication. As stated before, it has the capacity of helping to maintain a fluid film by conforming to the shape of the opposing surface. Electric motor bearings and railway axle-boxes use whitemetal bearings. In general applications a variety of whitemetals is used, tin base, lead base and intermediate. Alloys containing lead are cheaper, and improved performance under marginal lubrication conditions has been claimed. For high static loads, alloys with combined antimony and copper contents up to 20 per cent are used, though the increased compressive strength is accompanied by increased brittleness and increased risk of casting defects.

COPPER-BASE ALLOYS—These are widely used for general bearing purposes and especially for high loads.

TIN BRONZE OR PHOSPHOR BRONZE—This, usually with about 10 per cent of tin and $\frac{1}{4}$ per cent of phosphorus, is the classical alloy for high load applications. It will stand loads well above 10 t.s.i. without distortion and does not readily seize, probably because of its tough and tenacious tin oxide film.

LEAD BRONZE—This is tin bronze to which lead has been added to improve bearing properties. It reduces the bulk hardness of the alloy, thereby improving conformability, and at high spots, or under temporarily severe conditions, a small amount of lead squeezes over the surface and forms an extreme pressure lubricant, preventing seizure. Lead bronze is an excellent bearing material and should always be used in preference to phosphor bronze unless the high compressive strength of the latter is really needed. A variety of compositions is used, the 80/10/10 alloy being particularly popular. Nickel, up to 1 per cent, is sometimes used to increase strength. Nickel is also claimed to improve lead distribution, but it is doubtful whether the effect is significant.

GUNMETALS—Gunmetals, which are alloys of copper, tin, zinc, with or without lead, are widely used for the

TABLE 2. Characteristics of materials for fluid-lubricated bearings

Lining Material	Typical Composition %	Thickness (×0·001 in.)	Fatigue Strength p.s.i.	Wear Rating	Seizure Rating	Corrosion Rating
Tin-base whitemetal	7 Sb, 3 Cu, rem. Sn	12	1,900	1	1	1
		4–7	2,500	1	1	1
Lead-base whitemetal	1 Sn, 15 Sb, 1 As, rem. Pb	12	1,850	1*	1	2
		4–7	2,400	1*	1	2
Intermediate whitemetal	12 Sb, 3 Cu, 10 Pb, rem. Sn	12	†	1	1	1
Copper-lead	30 Pb, 70 Cu	12	3,400	3	3	4
Lead-bronze	24 Pb, 4 Sn, 72 Cu	12	5,500	4	4	4
Lead-tin overlay on copper-lead	10 Sn, rem. Pb, on 30 Pb/70 Cu	1·5	4,100	1	1	2
Lead-indium overlay on copper-lead	50 In, rem. Pb	1·5	4,100	1	1	2
Aluminium-tin	20 Sn, 1 Cu, rem. Al	12	4,600	2	2	1
Aluminium-tin	5–7 Sn, plus various hardeners	12	5,000	3–4	3–4	1

Wear. 1—least shaft wear; 4—most shaft wear.
Seizure Rating. 1—least tendency to seizure under conditions of oil starvation; 4—most tendency.
Corrosion Rating. 1—no attack; 4—marked attack by acidic oils.
* The bearing wear of lead base is somewhat higher than tin base.
† Not generally used for high alternating loads.

backings of bearings. Zinc improves casting properties, but is generally considered to be deleterious to bearing properties. Nevertheless alloys with small amounts of zinc, up to about 2 per cent, behave quite satisfactorily as bearings in many applications.

Other copper alloys such as manganese bronze and silicon bronze find successful use in a variety of bearing applications.

ALUMINIUM ALLOYS—These have yet to be fully assessed as general-purpose bearing materials. There have been a number of cases of successful use of aluminium alloys containing about 5-7 per cent of tin, with strengthening additions of copper, indium, magnesium, nickel, etc. They have the advantages of low cost and low weight when compared with bronzes, and there are probably many applications in which they could replace bronze successfully. Alloys of zinc and aluminium have also been used to some extent. One disadvantage of aluminium alloys is that in ferrous housings their high thermal expansion relative to that of ferrous material results in a compressive stress on the bush. If this is sufficient to cause yielding, the bush will tend to lose its interference fit on cooling. Consequently, alloys of fairly high yield strength are necessary if the bush is likely to become at all hot. For example, a yield strength of at least 5 t.s.i. is necessary to maintain fit after operation at 100 deg. C.

Oil-impregnated Bearings

A special case of the limited-lubrication bearing is the porous bronze or porous iron bearing, which is normally impregnated with oil. This type of bearing is widely used for applications which are inconvenient to lubricate by normal means.

While these bearings appear solid they have, in fact, a very fine interconnected porous structure, having been made by powder-metallurgy methods to give a predetermined degree of porosity, variable between 15 and 35 per cent. A final pressing operation confers close dimensional accuracy upon the product.

The bearing is normally impregnated with a suitable oil or grease, which is drawn out during running to provide a lubricating film.[2] Under suitable conditions, PV conditions of up to 60,000 (p.s.i. × ft./min.) can be carried. A normal life without maintenance is 1,000 hr., after which oil can be readily replenished. Normal operating temperatures are −10 deg. C. to +65 deg. C., but this can be extended with special lubricants. Typical applications are fractional refrigerators, vacuum cleaners, electric clocks, and similar types of equipment.

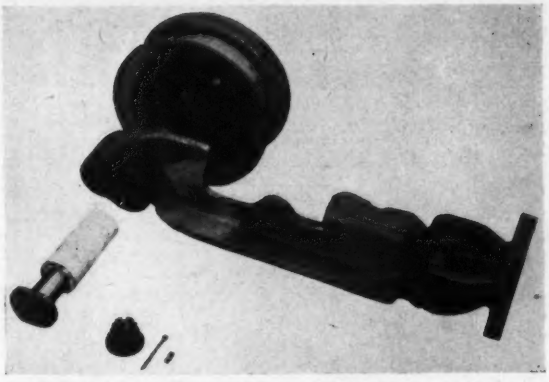


Fig. 6. A bush made of Orkot (United Coke & Chemicals Ltd.) used on a hook coil conveyor.

Fabric Bearings

Laminated fabric bearings are frequently used with advantage, especially with water lubrication. Under these conditions, they have a good wear resistance combined with low frictional losses. The low modulus of elasticity of the material gives conformability and assists in the maintenance of a fluid film. As with metal bearings, performance improves with running-in, as is illustrated by Fig. 5, showing the effect of running-in on friction.

Rolling mills offer an example of a suitable application for this type of bearing. The water for lubrication should preferably not exceed a working temperature of 85 deg. C. Fig. 7 shows another application, namely a stern-tube bearing fitted to an ocean-going cargo vessel.

Dry Bearings

Until recently, some sort of oil or grease has been practically indispensable for any sort of bearing. Now, however, materials are available which run under moderately severe conditions without the need for any kind of liquid or greasy lubricant. Such materials do not need oil or grease, an advantage in inaccessible positions, and where there must be no risk of contaminating food, paper, textiles, etc. They are also specially useful where temperatures are too high for ordinary lubricants and where lubricants would be washed away by, for example, detergent liquids.

The earlier types of dry bearings utilised solid lubricants, such as graphite or molybdenum disulphide. These are materials which bond readily to metal surfaces and shear easily within their bulk. Thus, for example, if two steel surfaces are coated with graphite and then slide together

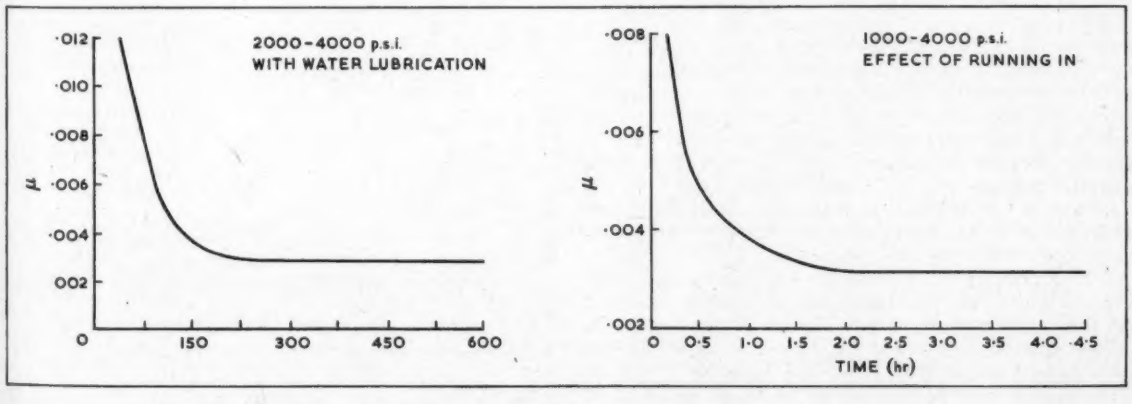


Fig. 5. Frictional properties for Orkot bushes.

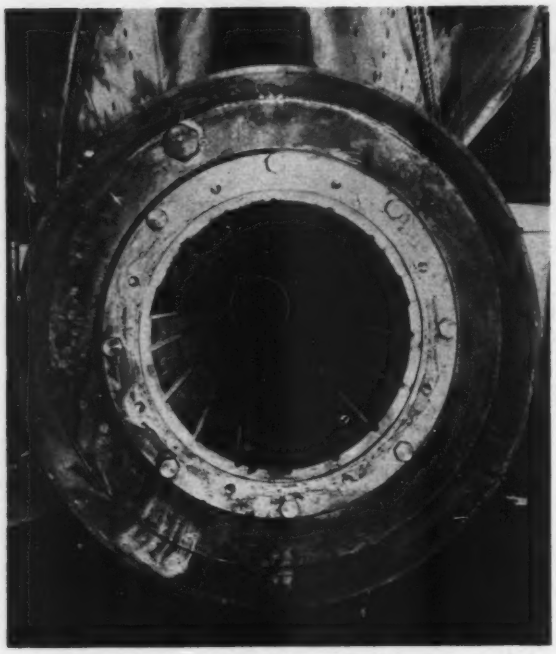


Fig. 7. Tufnol stern tube bearing fitted to an ocean-going cargo vessel.

under load, the graphite film shears within itself and the steel surfaces are protected. Such solid lubricants are quite useful, but their life is strictly limited, as the solid lubricant tends to be fragmented by shearing, and the fragments lost from the bearing area.

Performance can, however, be improved greatly by a preliminary treatment of the steel to give a porous surface, and then bonding a solid lubricant on to this surface by an organic binder. This type of treatment gives a much better performance than unbonded MoS_2. For example, in one series of tests on thrust washers operating at a load of 30 p.s.i. and a speed of 2,000 r.p.m., mild steel simply coated with MoS_2 failed after about fifteen minutes. With a phosphate-treated steel and organic bond, a life of over fifty hours was obtained under the same conditions.

The second approach to the problem of a dry bearing is to use a material which has little or no affinity for other materials, especially metals against which it is required to run. In the absence of such affinity, there will be little or no tendency to seize. Many organic materials have this property to some degree, especially certain plastics. Nylon, for example, has found limited application for bearings. Of all the known plastics, the one with inherently the best properties in polytetrafluoroethylene, a straight-chain polymer with all the hydrogen atoms replaced by fluorine. This material is extremely inert and has a low coefficient of friction by laboratory tests. It is, however, mechanically weak and it is probably because of this weakness, together with low thermal conductivity, that, in practice, its wear properties are not found to be outstandingly good.

Advantage can, however, be taken of the inherently good properties of p.t.f.e. by suitably combining it with other materials in one of the following ways:

1. A porous metal matrix can be impregnated with p.t.f.e. which is then sintered within the matrix, leaving a thin film on the surface. Various sintered porous metals can be used, but of those examined, the bronze gives far and away the best results; these results can be further improved by incorporating a small amount of lead with the p.t.f.e. A photomicrograph of this material is shown in Fig. 4(e). This material, now marketed in steel-backed form as Glacier D.U., is capable of prolonged operation under remarkably high loads and speeds (see Table 3). A similar material without a steel back is marketed by Bound Brook Bearings Ltd. under the trade name of Polyslip.

2. Various fillers can be mixed with p.t.f.e. to improve its strength, wear resistance and thermal conductivity. By suitable choice of fillers the wear rate of solid p.t.f.e. can be reduced by a factor of about 1,000. The performance of such materials is not as good as that of the above type, but they have the advantage of being machinable to size.

3. Thin layers of p.t.f.e. containing materials can be bonded to treated steel surfaces. Such layers have a life which is limited by their thinness, but which exceeds considerably the life of solid lubricant coatings. Thus a number of materials are now available for bearing applications which it is impossible or inconvenient to lubricate. These materials remove a major constraint from design, and are likely to be used to a rapidly-increasing extent in the future.

Special Anti-corrosive Bearings

In addition to the p.t.f.e.-containing materials referred to earlier, certain other materials are particularly suitable for corrosive environments.

CARBON can be used in acid or alkaline solutions, or with oil solvents with a suitably inert shaft material such as hardened stainless steel, stellite or chromium-plated steel

TABLE 3. PV values for Glacier D.U. bearings

(p.s.i. × ft./min.)	Mild Steel		Hard Steel 600 V.P.N.	
	1,000 hr.	10,000 hr.	1,000 hr.	10,000 hr.
Thrust bearings	25,000	12,000	30,000	15,000
Slides	12,000	6,000	13,000	7,000
Journal bearings:				
with unidirectional loads (load fixed relative to bush)	16,000	13,000	25,000	21,000
with rotating loads (load rotating relative to bush)	25,000	21,000	30,000	26,000
fixed load, oscillating shaft	30,000	25,000	33,000	26,000

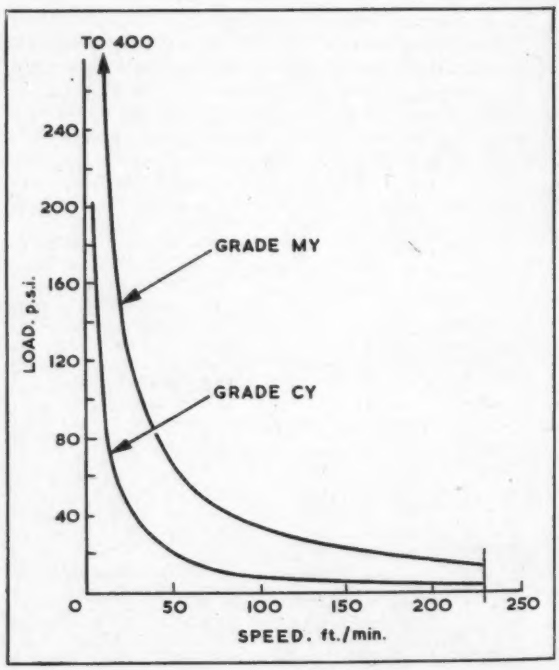


Fig. 8. Approximate continuous load/speed curves for Morganite carbon (dry) bearings.

(bronzes, case-hardened steel or aluminium alloys should not be used). Housings should have a low coefficient of expansion. Carbon is also used for some types of dry bearings. An indication of performance is given in Fig. 8.

NYLON is inert to alkalis, solvents, organic acids and dilute mineral acids, but not to concentrated mineral acids, molten phenol or formic acid. It is used successfully as a bearing in applications requiring such corrosion resistance. With no lubrication, its value is limited, but with a trace of a lubricant its performance is much improved.

Flexible Bearings

Plain rubber bushes of either cylindrical or conical form are ideally suited when the housing and shaft dimensions have wide manufacturing tolerances. The Harrisflex type are preloaded during assembly in an axial direction against predetermined stops. The cylindrical type should be chosen where the loading is purely radial, the conical type being used where there is axial and radial movement.

The main function of the bonded flexible bearing in which rubber is bonded between two concentric metal tubes and then pre-loaded by the expansion of the inner tube is to permit oscillating movement without lubrication; typical applications being the pivots on shaker screens and the eyes of leaf springs. They are also fitted to prevent racking due to thermal expansion or other causes. They are used in pin-type couplings to permit malalignment and cushion shock loads. As all movement takes place within the rubber there is no wear and no lubrication is required.

The four types of loading sustained by this type of bearing are torsional, radial, axial and angular. The characteristics of a bearing can be altered by modifying its proportions, the thickness and hardness of the rubber, or by changing the shape of the metal sleeves. In many applications relative freedom is required in one direction with constraint in others. This can be achieved by altering the shape of the bearing. Spherilastik bearings (see Fig. 9), for example, permit large angular movements in all planes and sustain heavy radial and axial loads.

Natural rubber is normally employed because it has better mechanical characteristics than the synthetics, and where excessive oil is present protection can be obtained by the use of oil-resisting paint or seals, although for some applications oil-resisting synthetic rubber may be used in place of natural rubber. Bearings made with natural rubber are not adversely affected by temperature within the range of −30 deg. C. to +70 deg. C., and will perform satisfactorily at a temperature of −40 deg. C. if the dynamic conditions are not too severe. For extremes of temperature silicone rubber may be employed.

BEARINGS AND BEARING MATERIALS

We wish to acknowledge the co-operation given by the following firms in the preparation of this survey. The details given here in classified form are not exhaustive, but are intended to simplify the work of the designer in making an initial selection. Firms listed supply materials in ingot, bar or tube form or as finished bearings to order.

Whitemetals
A. Cohen & Co. Ltd.
Paul Bergsoe & Son.
Delta Metal Co. Ltd.
Eyre Smelting Co. Ltd
Glacier Metal Co. Ltd.
Glyco Metal Co. Ltd.
Hoyt Metal Co. of Gt. Britain Ltd.
Magnolia Anti-friction Metal Co. of Gt. Britain
J. Stone & Co. (Charlton) Ltd.

Aluminium Alloys
A. Cohen & Co. Ltd.
Eyre Smelting Co. Ltd.
Glacier Metal Co. Ltd.
Hill, Alzen (Sales) Ltd.
Main Metal (Gt. Britain) Ltd.

Copper Alloys
Barronia Consolidated Ltd.
Thos. Bolton & Sons Ltd.
A. Cohen & Co. Ltd.
Crown Metal (Wednesbury) Ltd.
Carobronze Ltd.
E. Chalmers & Co. Ltd.
Glacier Metal Co. Ltd.
Glyco Metal Co. Ltd.
John Holroyd & Co. Ltd.
Hoyt Metal Co. of Gt. Britain Ltd.
Enfield Rolling Mills Ltd.
Eyre Smelting Co. Ltd.
Magnolia Anti-friction Metal Co. of Gt. Britain.
Manganese Bronze & Brass Co. Ltd.
I. Stone & Co. (Charlton) Ltd.
Phosphor Bronze Co. Ltd.
Williams Alexandra Foundry Ltd.

Asbestos
J. W. Roberts Ltd.

Porous Bearings
Bound Brook Bearings Ltd.
Manganese Bronze & Brass Co. Ltd.
Morgan Crucible Co. Ltd.
Sintered Metal Components (Chard) Ltd.

Jewel Bearings
J. P. Filhol Ltd. (Synthetic sapphire and ruby; natural agate and glass).

P.T.F.E. Impregnated or Based
Beldam Asbestos Co. Ltd.
Bound Brook Bearings Ltd.
Glacier Metal Co. Ltd.
Permali Ltd.
Polypenco Ltd.

Nylon-lined
Howard Clayton-Wright Ltd.
Polypenco Ltd.

Rubber
Andre Rubber Co. Ltd.
Howard Clayton-Wright Ltd.
Dunlop Rubber Co. Ltd.
Precision Rubbers Ltd.
Metalastik Ltd.
Silentbloc Ltd.

Laminated Plastics
Ioco Ltd.
Coin Insulation Ltd.
Tufnol Ltd.
Micanite & Insulators Ltd.
Vulcascot (Gt. Britain) Ltd.
United Coke & Chemicals Ltd.

Carbon
Morgan Crucible Co. Ltd.
Vulcascot (Gt. Britain) Ltd.

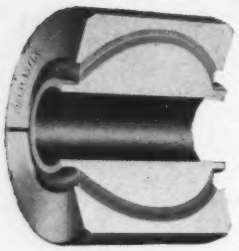


Fig. 9. Sectional view of a Spherilastik (Metalastik Ltd.) bearing.

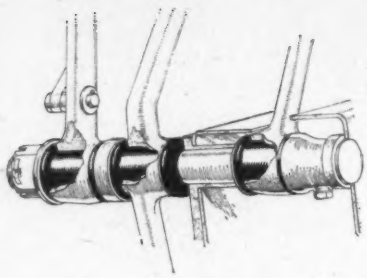


Fig. 10. Harrisflex bearings applied to typical clutch, brake and accelerator pedals. (Photo: Howard Clayton-Wright Ltd.)

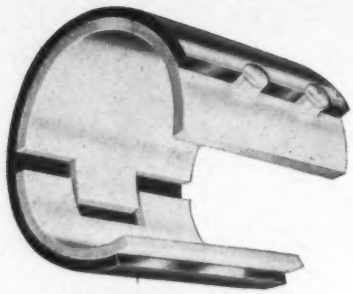


Fig. 11. Combination of steel-backed nylon bearing in Clayflex housing. (Photo: Howard Clayton-Wright Ltd.)

Jewel Bearings

These are a specialised type of bearing used in high-grade instruments, compass mountings, also in watches and clocks and for the latter are generally to less exacting specifications. The three main types of bearings are the V-jewel, the ring stone which may contain either a parallel bore or a radiused bore (giving a constricting throat effect) and the end stone, the bearing surface of which may be either flat or curved to give a raised centre. The sizes of these bearings are laid down in B.S.904 ("Dimensions of Instrument Jewels") which exclude jewels for watches and clocks and cup jewels for integrating meters. The shafts used with these bearings are usually made from a hardened steel or a high-quality alloy steel, and although they will operate satisfactorily in a dry condition, usually a faint trace of refined meter oil is used.

REFERENCES
1. "Effect of lining thickness on fatigue strength of whitemetal on steel bearing". Duckworth & Walter, *Proc. of Int. Conf. on Fatigue of Metals*, I.Mech.E., 1956, p. 588.
2. V. T. Morgan and A. Cameron. I.Mech.E. Conference on Lubricants, 1957, p. 151.

A valuable survey of the main types of BALL AND ROLLER BEARINGS available to the designer and their correct application will be published in our November issue.

NEW TYPE OF STEPPING TRANSISTOR

DEVELOPMENT of a p-n-p-n semiconductor element that can serve as the basic building block of a silicon stepping transistor has been announced. It has potential application to digital computers, push-button dialling and telephone switching.

The highly adaptable stepping transistor element was described by a Bell Telephone Laboratories' engineer at the recent Western Electronic Show and Convention in San Francisco.

The four-terminal device acts as a pulse-controlled on-off switch. It may be used as a basic stage in building up certain logic circuits in digital computers, such as for counting and decoding. By using one element to drive two others, versatile decoders can be made.

A more complex device, which is fabricated from a single piece of silicon, can also perform these logic functions. As a prototype arrangement, a stepping transistor with four stages or elements has evidently already been produced.

The stepping transistor, as fabricated on a single piece of silicon, performs the function of a complex circuit. Hence it is referred to as a "functional device". The concept of a functional semiconductor device is a promising approach to micro-miniaturisation.

The stepping transistor itself is the result of work originated in 1954 by I. M. Ross of Bell Telephone. His object was to build a semiconductor device that would function similarly to a gas stepping tube: a digital counter capable of carrying out at high speeds many of the same functions usually performed by complex circuitry or else at low speeds only by chains of relays and mechanical stepping switches.

The gas stepping tube utilises the bi-stable voltage-current characteristic of a gas discharge for its operation. Unidirectional transfer of voltage between its electrodes —one anode and several cathodes—is obtained by the non-symmetrical geometry of the latter's construction.

The stepping transistor utilises a p-n-p-n transistor as the bi-stable element. The design of the structure results in a bi-stable voltage-current characteristic between a single common electrode and a set of multiple electrodes. Non-symmetrical geometry is employed to obtain a unidirectional transfer of voltage.

Also, unlike the gas stepping tube, close proximity between stages is not basically required in the stepping transistor. This is why stepping transistor elements comprising single four-terminal stages can be separately encapsulated and connected externally.

The current level at which these devices are operated can be designed within the range of 1-100 milliamperes with supply voltages of 10-100 volts. They have been operated at speeds up to one million pulses per second. With improved designs, it is expected they will operate even faster.

PRESENTATION OF GEAR DESIGN DATA

Environment, as much as the type of load to be carried, affects the correct use of gear units. The author suggests here how these factors must be considered by the designer at the outset

by R. GARDINER *

STANDARDISATION of design does not imply that units will satisfy all possible contingencies irrespective of application, but where a sufficient range of standard units is maintained it is usually a matter of well-informed selection. This can be exercised effectively only when all relevant information is made available.

This is particularly applicable to gears, which, as transmission units, are subject to a surprising number of extraneous conditions imposed by either the prime movers or the driven machines. To illustrate this point, a worm gear unit—by far the most widely used form of industrial drive in practically every industry—may be taken as an example.

The selection of the type of gear unit must first be considered. A first glance may suggest that, as spur or helical gears have an efficiency of 97-98 per cent regardless of ratio (compared with worm gears where the efficiency varies substantially according to ratio), the former may be the ideal choice as there would be less wasted power to be dissipated as heat. Where, however, the ratio is beyond the limitations permissible for spur gears, this choice would mean either using a large, expensive, inefficient, slow-speed motor or, alternatively, multiple reduction gears with a multiplicity of bearings making a bulky and costly structure.

Economy of space is particularly important where gangways are involved, such as with conveyor drives as the example illustrated in Fig. 1, where the right-angle drive permits the gear, motor and bed to lie snugly alongside the conveyor with very little intrusion into the gangway.

It is most important that the gear unit suppliers are given details of the ambient temperature in the vicinity of the site, together with the duration of work periods as, from known data, the temperature rise due to efficiency loss can be determined. This, when added to the initial temperature, must fall within the permissible maximum.

Applications

Basic capacities for worm reducers should be based on a working day of twelve hours with uniform loading, and from Table 2 a multiplying factor can be found according to the duration of service and the nature of the load. Table 1 gives sufficient applications for guidance in classifying the nature of the load for use in conjunction with Table 2.

EXTERNAL LOADS—External loads fall under two headings: avoidable and unavoidable. Perhaps the most dangerous example of avoidable loading occurs when a gear unit is coupled to a long line shaft as shown in Fig. 2 and where the shaft is located axially by a thrust bearing on a bracket or hanger at the end of the shaft remote from the gear. Variations in atmospheric temperature between hot days and cold nights are sufficient to impose a terrific end thrust directly on to the gear bearings, over and above their normal duty. This condition can ideally be avoided

* *David Brown Industries Ltd.*

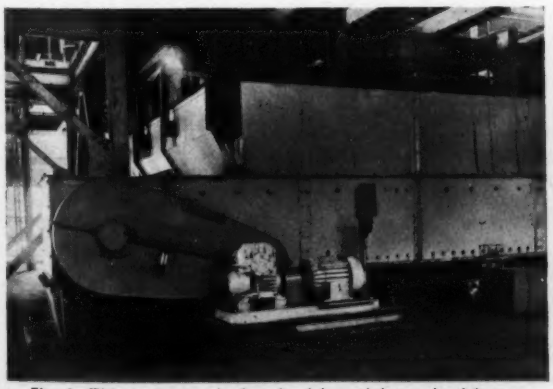


Fig. 1. This conveyor is fitted with a right-angle drive to avoid any intrusion of the gear and motor unit into the gangway.

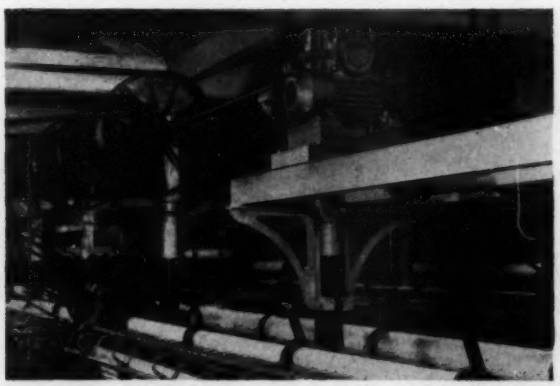


Fig. 2. Gear unit coupled to a long line shaft in a textile works. Excessive end thrust on the gear bearings may be avoided by interposing a flexible coupling.

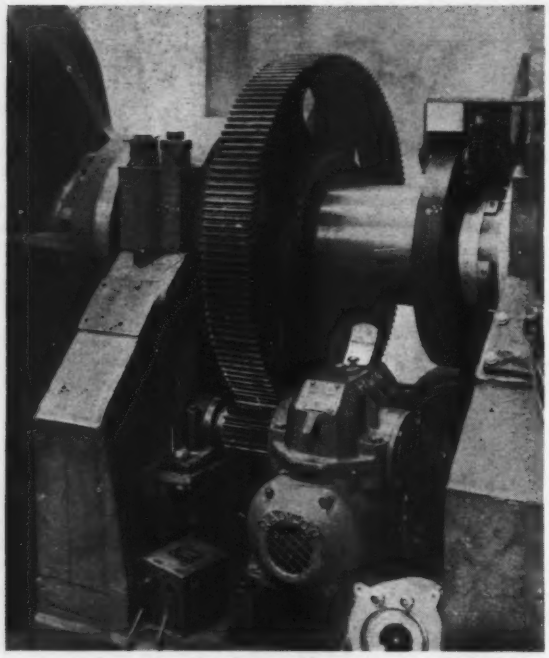


Fig. 3. Size 5 Radicon gear unit driving a cobalt bomb cancer-treatment machine.

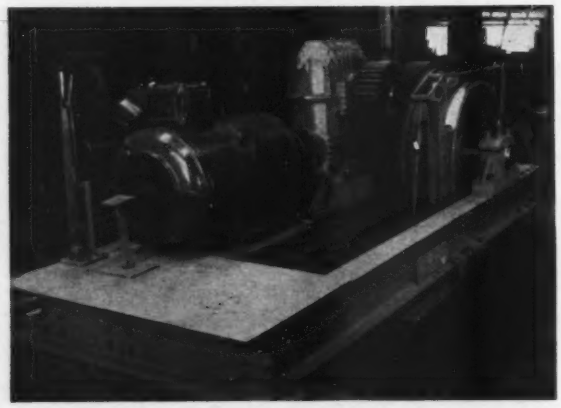


Fig. 4. Size 14 Radicon drive installed for underground rope haulage. Compare the size of pinion with that in Fig. 3.

by interposing a flexible coupling between gear unit and line shaft; this also takes care of any slight misalignment. It is, however, possible to avoid the excessive thrust condition by installing the location bearing immediately adjacent to the gear so that expansion with its resultant thrust is away from the unit.

The unavoidable external loads are such that details should always be given to the gear makers. Frequently it is necessary to mount a pinion, pulley or sprocket on the low-speed shaft extension and, while most units have a substantial capacity for such overhung load, provision can be made for the internal fitting of an additional roller bearing when necessary. Extreme cases may necessitate the provision of an outboard bearing.

When determining the magnitude of overhung loads, it is quite frequently found that there is a misconception of the actual conditions due to a mistaken belief that a small overhung pulley imposes less load than a large one. Actually the reverse is the case, as the radial load applied to the shaft can be taken approximately as

$$\frac{\text{torque} \times 3}{\text{pulley radius}}$$

Where a belt pulley is overhung, the conditions are more severe than those obtaining with an overhung pinion where the radial loading is

$$\frac{\text{torque}}{\text{pinion pitch line radius}}$$

From these formulæ it is obvious that, where pulleys or pinions are small, the loads imposed on the bearings must be most severe. Dependent upon the lateral position of the imposed load, the bearing load and the stress in the shaft due to combined bending and twisting may be too great without the additional bearing.

Comparison of Figs. 3 and 4 shows the difficulty of judging by sight. Fig. 3 shows a Size 5 Radicon driving a cobalt bomb cancer-treatment machine, in which the second reduction pinion is quite small and an additional journal load is imposed sufficient to necessitate an outboard bearing. Fig. 4 illustrates a Size 14 Radicon drive, for an underground rope haulage, which has an overhung spur pinion that is much larger in proportion to the Radicon, but the increased journal load can be accommodated by the extra roller bearing within the unit.

Consideration of the loading conditions cannot be complete without knowledge of the initial loads imposed by the gears themselves, and it is essential that all relevant details as to the nature of the drive be supplied to the makers.

Other instances where loads must be properly assessed occur with units having vertical low-speed shafts, as in the case of stirrer drives when the paddle shafts are usually coupled solidly to the output shafts of the gear units. Here the weight of the paddles and the axial thrust must be taken into consideration.

TABLE 1. General guide to load characteristics for gear applications

Application	Type of Load
Agitators and mixers:	
liquid or emulsion	U
variable density	M
Blowers: centrifugal	U
Roots type	M
Brick-making presses	H
Conveyors: uniformly loaded	U
rough or non-uniform material	M
reciprocating and shakers	H
Cranes: travel motion	U
hoisting	U
Drawbench	M
Elevators	U
Feeders: pulsating	M
reciprocating	H
Hoists	M
Kilns	M
Laundry plant: tumblers	M
washers	U
Lifts	M
Line shafts	U
Mills—hammer	H
Paper mill drives: calenders	U
beaters	M
Pumps: centrifugal or gear	U
reciprocating, three-flow	M
reciprocating, single cylinder	H
Rubber plant: calender	M
masticator	H
mixer	M
Screens, vibrating	H
Stone crushers	H
Textile: carding machines	U
looms	M
Wire-drawing machines	U

U—Uniform load. M—Moderate shock. H—Heavy shock.

TABLE 2. Factors to be considered in assessing load capacity

Prime Mover	Hours per day	Nature of Load from Driven Machine		
		Uniform Load	Moderate Shock	Heavy Shock
Electric motor or steam turbine	24	0·80	0·67	0·50
	12	1·00	0·80	0·57
	8	1·10	0·90	0·62
	4	1·25	1·00	0·71
	2	1·33	1·10	0·80
Multi-cylinder internal combustion engine	24	0·67	0·57	0·44
	12	0·80	0·67	0·50
	8	0·90	0·74	0·53
	4	1·00	0·80	0·59
	2	1·10	0·90	0·67
Single-cylinder engine	24	0·57	0·50	0·40
	12	0·67	0·57	0·44
	8	0·74	0·61	0·48
	4	0·80	0·67	0·53
	2	0·90	0·74	0·57

Flexible couplings may be advisable, depending on the set-up, as there are causes of misalignment that are not always obvious. For example, a driven machine may have a temperature rise greater or less than that of the gear and there may be a difference in the relative expansion and therefore a corresponding variation in height and alignment. Another example is a gear with ball bearings driving a machine with plain bearings which might have appreciable clearance when the shaft is lifted when running as compared with its position when lined up statically. The flexibility of foundations must also be taken into consideration, particularly when units are bolted direct on to structural steelwork.

A point of major importance not always considered in the layout stage is the question of ratio. Gear-cutting hobs are expensive and the individual setting up of a machine for cutting a special gear is both costly and time wasting. If the approximate speeds are given to the gear maker and he is allowed to select the nearest standard ratio from the very substantial range of stock units which is maintained, it is usually possible in the initial stages to accommodate any slight variation. This is of particular advantage when subsequent repeat orders are placed and strict interchangeability is necessary.

Another factor that occasionally arises is in connection with irreversibility. It should be emphasised that no worm gear can be guaranteed to be irreversible, however high the ratio and however low the lead angle of the worm. If this feature is necessary, the gear firm should be asked to put up a proposition for a roller hold-back, i.e., a freewheel device which can be built on to the gear unit.

All the above conditions are given to underline the importance of giving all relevant data in the interests of safety, efficiency and frequently of economy. The following categorical list should serve as a reminder of such details as may be applicable in each individual case.

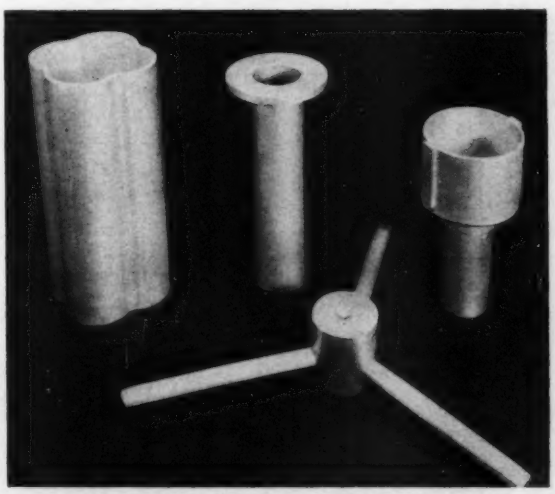
1. Horsepower of prime mover or output torque required for driven member: the latter is most important for slow-speed drives of 10 r.p.m. or less.
2. Input speed of gear unit.
3. Output speed of gear unit.
4. Number of units required.
5. Type of unit.
6. Relative shaft dispositions.
7. Application of drive.
8. Total daily hours of running. If running is intermittent, details of duty cycle should be given with particulars of any abnormal starting loads.
9. Details of any reversing or shock loads.
10. Details of any external loads imposed on gear unit.
11. Particulars of any abnormal conditions, e.g., ambient temperatures, humidity, etc.
12. Are couplings, bedplates or other ancillary equipment required? Where couplings are to be supplied, diameters of motor and driven shafts should be given.

LATERAL IMPACT EXTRUSION—A NEW TECHNIQUE

A FURTHER form of impact extrusion said to be capable of instantaneously and completely fabricating such a complex shape as the hub and spokes of a steering wheel has been developed. It is known as lateral impact extrusion, the "lateral" referring to the direction of metal flow. Until now, impact extrusions have been produced as a result of making metal flow up around a punch, down into a die, or by a combination of these. With lateral impacts, there is an additonal flow of metal radially at any angle from the direction of the impact stroke.

To illustrate the potentialities of the process, a part consisting of a formed hub with three spokes extending outward from the hub was designed and produced in one operation, cold, from a cylindrical slug.

Conventional impact extrusions are preferred where strength and close tolerances are desired for products with intricate design features; the process is used frequently for operations that are beyond the capabilities of other metalworking methods. These same considerations would apply in choosing lateral impact extrusion, say the Aluminium Co. of America, who have developed the latest technique. It will permit economical production of parts that combine an intricate hub or core with such lateral extensions as spokes or vanes. Such a part would evidently be free of porosity and brittleness, and have toughness and high wrought strength throughout.



A steering wheel produced by lateral impact extrusion is shown here with components made conventionally; i.e. (from left) reverse impact, made by metal flow up around a punch; forward impact, made by metal flow down into a die; and combination impact, made by metal flow up around the punch and down into the die.

designer's notebook

Linear and Rotary Fly-Back Mechanisms

IN fly-back mechanisms an operated member is progressively advanced along a predetermined path (the forward stroke) until, at a predetermined point, it is returned at a rapid rate to its starting point ready for the next stroke. Such mechanisms are used for various purposes and are sometimes employed for scanning a series of cam members as used in the selecting mechanism of a multi-channel radio apparatus.

In the accompanying simplified drawings two patented mechanisms of this type are shown, one providing a linear movement of the carriage, the other an arcuate one.

In the mechanism having a linear fly-back (illustrated on this page) the carriage is a sleeve (A) which slides on the tops of the threads of a lead screw (B). A spur gear (C) is used to rotate the lead screw. A wire spring (D) urges the carriage towards the right-hand side plate of the mechanism. Underslung from a lug on the carriage sleeve is a short crankshaft which carries a spur gear (E). This spur gear engages the lead screw in the manner of a worm wheel. The crankshaft carries a pin (F) which makes contact with and slides along a fixed rod (G). This rod serves also to restrain the carriage from rotation.

When the carriage is at the right-hand side of the lead screw, as in the right-hand view, it will be seen that the spur gear is restrained from counter-clockwise rotation by the crankpin bearing against the fixed rod (G). The spur gear therefore acts as a nut fixed to the carriage sleeve, and rotation of the lead screw will cause the carriage to move to the left. This movement will continue until the crankpin escapes over the end of the rod, whereupon the carriage will move quickly to the right, the spur gear rotating upon the screw thread, as upon a rack, as the carriage rapidly moves back to the right, urged there by spring (D). In the example shown the gear size was so calculated that the arcuate movement of the crankpin brought it gently into contact with the guide bar at the right-hand end of the carriage travel.

In the second mechanism (see Fig. 2) the fly-back is in an arcuate path. The driving member is a sun wheel (A). This is driven by a suitable driving gear (B). The carriage (C) consists of an arm carrying a planet gear (D) which meshes

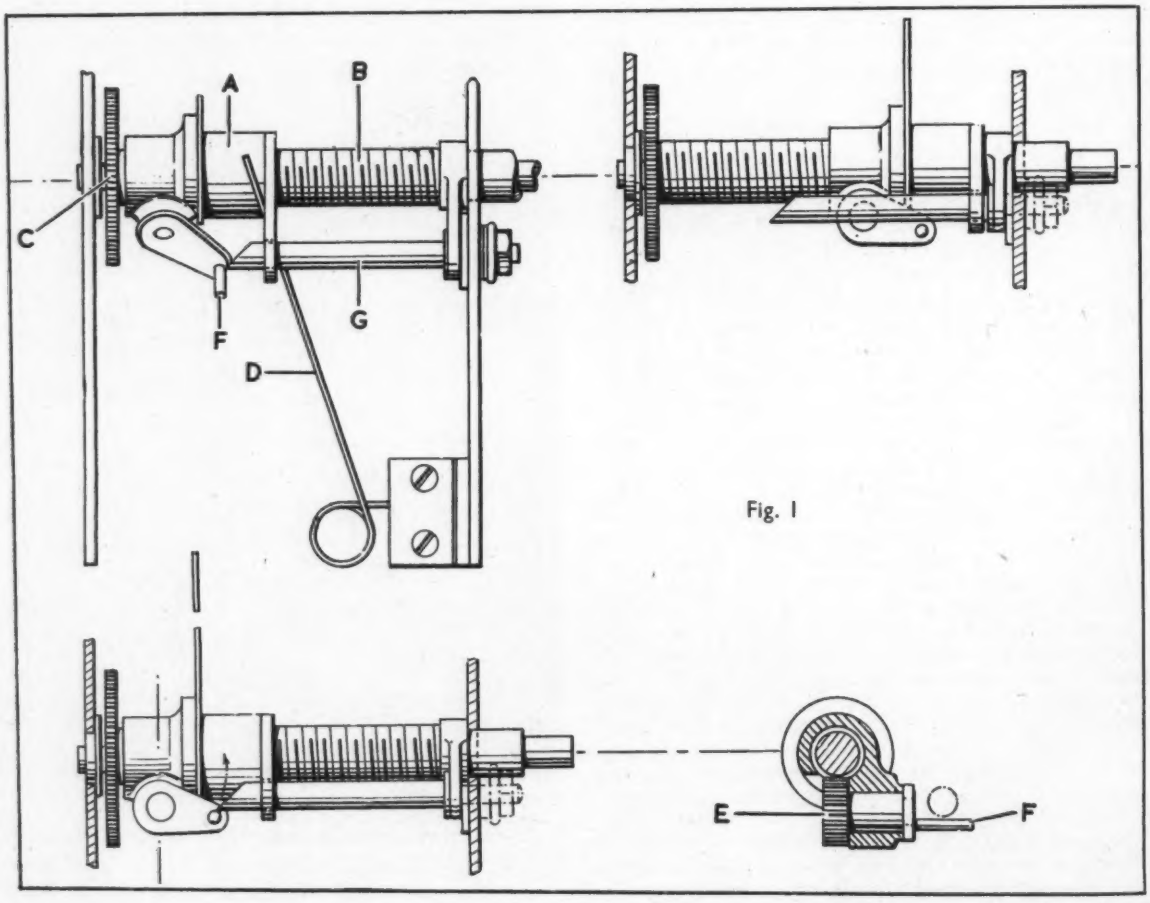


Fig. 1

with the sun gear and is free to rotate on the shaft (E). A crank (F), rotating with the planet wheel, has a throw greater than the pitch circle diameter of the planet wheel. The crank carries a pin (G) which slides around a segmental guide member (H) which is rigidly mounted on the shaft (E). The sun wheel rotates anti-clockwise, as shown by the arrow, and a torsion spring (J), acting between the carriage (C) and an abutment (K) on the plate (L), tends to urge the carriage in a clockwise direction. A stop (not shown) limits the clockwise movement of the carriage, stopping it in a position in which the crankpin (G) is just clear of the segmental guide member (H).

When the sun wheel is driven continuously in the direction of the arrow, the carriage is driven in an anti-clockwise direction with the crankpin (G) engaging the guide member segment (H). When the crankpin reaches the end of the guide member, the planet wheel is free to rotate and the carriage is returned to its starting point, by the torsion spring (J), in a clockwise direction until the return stop is engaged. The rotation of the sun wheel then brings the crankpin back into engagement with the guide member ready for the next anti-clockwise movement.

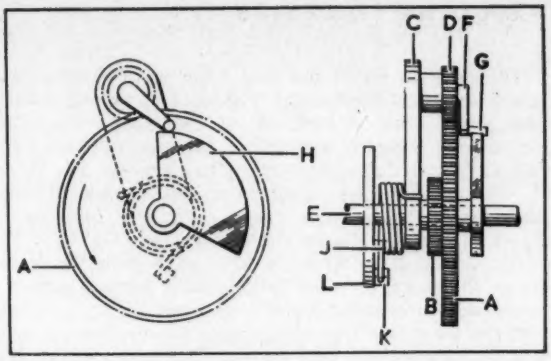


Fig. 2

If desired the guide member may be adjustable angularly about the shaft (E) so that the relationship of the fly-back movement to the sun wheel may be changed.

S. Z. Milledge and Frenchay Products Ltd.

Random Feed Device for Paddle Chains

FEEDING packets into a paddle chain moving at right angles across their direction of motion is a familiar practice. In the application described, however, it was not possible to provide a positive feed motion synchronised with the paddle chain, which would normally be the case to prevent jamming of the packets against the corner at the mouth of the discharge lane. The problem here was how to feed packets moving at random frequency along the feed lane into a paddle chain moving across it at constant speed.

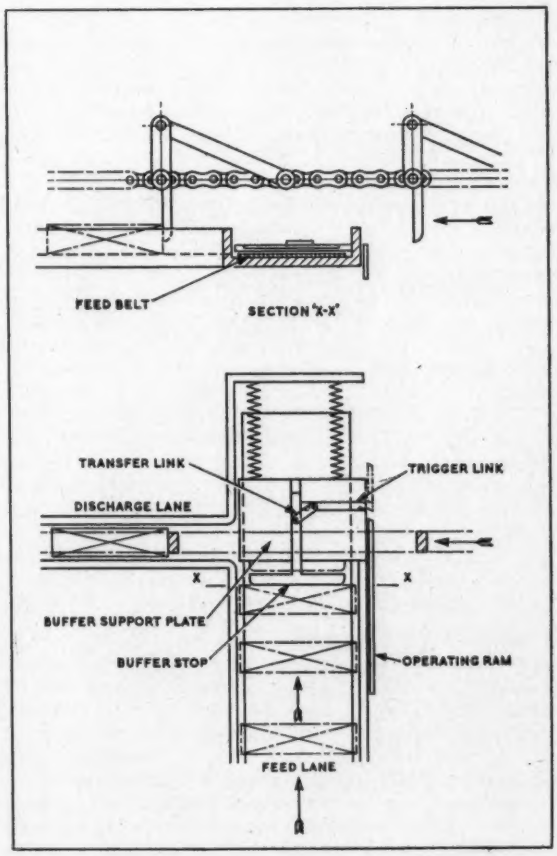
The mechanism consists essentially of a buffer stop which is triggered by the packets themselves. The buffer stop is normally in the position shown by the full line in Fig. 1. As the packets are fed on to it by the belt, the stop tries to move backwards, pushing against the trigger link via the transfer link.

When the operating ram, which is synchronised to reciprocate at the frequency of the paddles moving across the feed lane, is in the appropriate position, the trigger link is free to move outwards to engage it. This condition is shown, chain dotted, in Fig. 1. The operating ram now moves the buffer support plate together with the buffer stop backwards against the loading springs, thus permitting the paddle to pick up the packet and feed it into the discharge lane.

The operating ram dwells in the rear position until the packet clears the feed lane, then moves forward to its original position, allowing the spring-loaded buffer support plate and buffer stop to push any following packet out of the way of the next paddle.

At the end of the return stroke the support plate strikes the stop provided by the right-hand feed lane guide, and the buffer stop is free to return to its original position due to its momentum. It will then remain inoperative until the next packet moves into position.

E. H. Bush, A.M.I.Mech.E.



CONTRIBUTIONS INVITED

Readers are invited to submit for publication in "Designer's Notebook" details of ingenious devices and mechanisms which could be used more widely than in their original application.

Contributions, which will be paid for, should preferably be about 300 words in length and be accompanied by an explanatory diagram or sketch. The designer's name will be published, unless requested otherwise.

Contributions should be sent to The Editor, "Engineering Materials & Design", Drury House, Russell Street, London, W.C.2.

The problem set in our July issue was "to provide a simple means of mechanical reciprocation with an adjustable dwell period at each end of the stroke". The most elegant and complete solution to this was received from Mr. B. Grinsted. An alternative mechanism by Mr. M. L. S. Flint, though less satisfactory, was considered very ingenious.

By B. Grinsted, B.Sc., A.M.I.Mech.E. (see Fig. 1)

A quadrant plate (A) is caused to pivot about the centre (B) of the circle, of which its boundary forms a part, by means of a connecting rod (C) operated by a crankshaft (D). On the centre line of the plate A and fastened to it is a short segmental rack having three gear teeth in the example shown. These teeth engage four corresponding teeth which project from the arcuate profile of a plate (F) which is free to pivot about its centre. To this plate, which reciprocates to and fro, the output link (G) is connected. Three rollers (G) are attached to the underside of plate (F) by T-piece (H). These rollers are spaced at 90 deg. to each other with their centres on the pitch circle of the gear teeth. At the middle point of the reciprocation the central roller engages a cut-out in the arcuate profile of the quadrant plate as shown in the scrap perspective view. The cut-out is semi-circular, topped by two short cam surfaces. As plate (A) swings away from the central position it will be seen that plate (F) is moved by the gear teeth so that the central roller moves out of the central cut-out by riding up the cam surface on to the arcuate profile lifting the last driven tooth clear. In so doing it has pivoted about the centre of plate (F) through 45 deg., the roller at 90 deg. to it also making rolling contact with the profile of plate (A), thus providing a positive termination to the movement of plate (F) which remains "locked" until the quadrant plate returns again after reversing. The teeth are designed for correct re-engagement with initial contact on the pressure line. During the dwell period the quadrant plate continues to pivot about point (B).

Variation of the dwell period can be symmetrical, with equal dwell period at each end of the stroke, or it can be varied at each end of the stroke. The adjustment for this is by means of the knurled central turnbuckle of the left and right hand threaded screw in the connecting rod (C), which enables the length of the rod to be varied. The stroke also could be made adjustable, by introducing a slot into the plate (F) with an adjustable pivot point for the output link (J).

By M. L. S. Flint, S.I.Mech.E. (see Fig 2)

The alteration to the dwell period of this mechanism relies on a yoke follower, which carries two cam roller followers, so designed that the angle between the rollers can be varied. The rollers can be moved together or apart in an arcuate T-slot. Unfortunately, if this principle is employed it is difficult to provide positive reciprocation with an alteration to each dwell period.

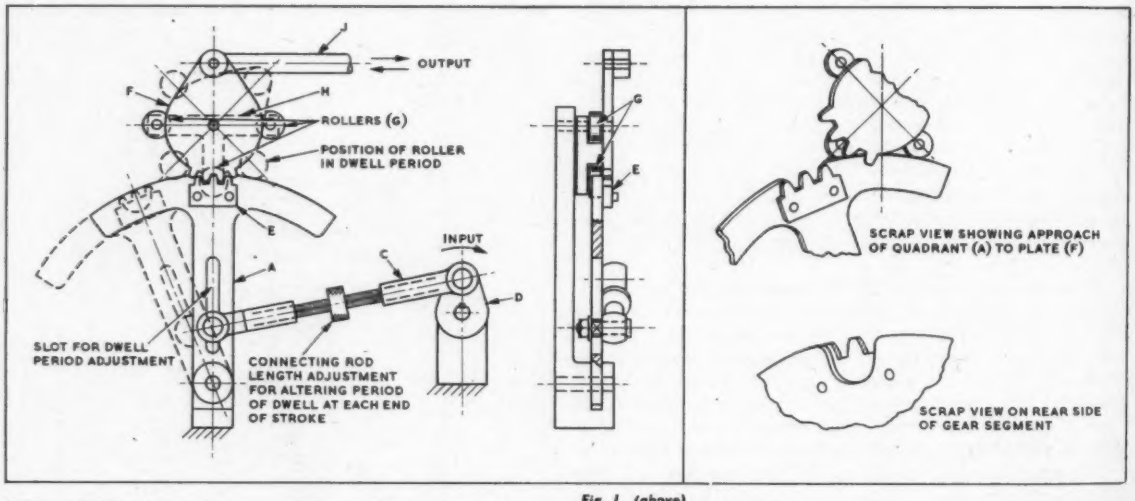


Fig. 1 (above)

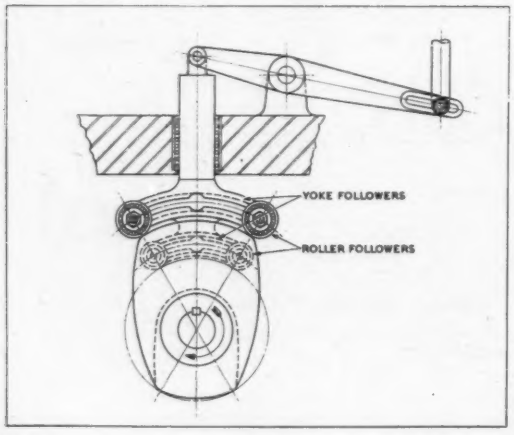
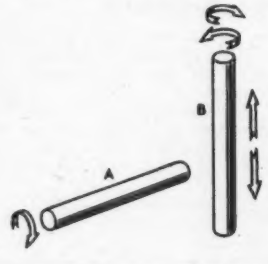


Fig. 2 (left)

Best solutions to problems set in "Design Bureau" are published and paid for. Send your solution for this month, with a rough diagram if necessary, to The Editor, E.M.&D., marked "Design Bureau (October)".



THIS MONTH'S PROBLEM

To devise a mechanism by means of which rotation of shaft A causes reciprocation of shaft B, both about its axis and also lengthwise.

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Improvement in Floating Zone Technique

THE primary limitation in conventional floating zone refining is the fact that for any given material there is a maximum height of molten zone which can be supported by the surface tension. Small diameter rods can be melted without exceeding this maximum height. However, in larger diameters, by the time the rod has been melted through, the height of the zone has become so great that the surface tension can no longer hold the volume of molten material.

A new method devised at Bell Telephone Laboratories overcomes this difficulty by using specially shaped sections, such as flat plates and tubes. These shapes provide a cross section small in thickness to permit melting through without exceeding the maximum height, and large in width to increase the total cross-sectional area treated.

Stable, wide molten zones have been maintained experimentally in one or both cross-sectional shapes, in materials such as silicon, iron, tin, gold, lead and bismuth.

The new method works well at very small plate thicknesses in contrast to the rod floating zone method, in which the maximum stable zone height decreases to zero as the rod diameter decreases. Such a decrease in maximum zone height can be avoided in the new method. Hence, treatment of sheets in the order of mils or less in thickness becomes feasible.

This new technique should make the floating zone method applicable to materials for which the conventional method is not practical.

Advances in Iron-Aluminium Alloys

Iron-aluminium alloys with a relatively high aluminium content (about 15 per cent by weight) have certain promising properties of heat resistance, reduced specific weight, hardness, corrosion resistance and magnetic properties.

American developments have yielded an alloy with 16 per cent aluminium and a tertiary alloy with an addition of 3 per cent molybdenum which were used respectively for electrical transformer sheet and compressor blades.

Hitherto, alloys with 16 per cent aluminium could not be produced with an elongation exceeding 3 per cent. This is believed to be due to impurities which raise brittleness by the formation of micro-cracks and by a tendency for a coarse grain.

For these reasons, a Russian study recently published is of interest. The results of this investigation, in which the addition of rare metals was tested for their effect on iron-aluminium alloys, have shown that the main cause of brittleness is the presence of oxygen. The minimum oxygen content is obtained by induction melting in a helium atmosphere. The iron must first be de-oxidised by carbon in vacuo or by hydrogen.

A substantial grain refinement is achieved by additions of titanium or combined additions of cerium and zirconium, cerium and molybdenum or cerium and vanadium. Boron and vanadium in quantities up to 0·50-0·2 per cent significantly increase the hardness of the alloys. The strength of the alloys increases from 22 to 37 kg/mm² (31,300-52,600 p.s.i.) with an addition of 0·05 per cent of boron. Tantalum (0·2 per cent) and zirconium (0·5 per cent) increase the strength by 20-25 kg/mm² (28,450-35,600 p.s.i.) and also the impact value and ductility in hot rolling.

Another feature discovered is the direct relation between the intensity of magnetisation and the capacity of the alloys for deformation in the hot state. The magnetic alloys (16 per cent aluminium, or less) are easily rolled into strip. Non-magnetic alloys are brittle even when hot.

Compound additions of cerium (0·25 per cent) with vanadium (0·25 per cent) and molybdenum (1·8 per cent) shift the maximum aluminium content for magnetic transformation from 16-14 per cent aluminium.

Additions to iron-aluminium alloys do not impair their corrosion resistance. At 1,200 deg. C. these alloys hardly suffer oxidation. Their corrosion resistance is similar to that of stainless steels.

New Nuclear Stainless Steels

Two new nuclear stainless steels are now commercially available in the U.S.A. One is a low cobalt steel, containing between 500 and 2000 p.p.m. used for containers and internal structural members in atomic reactors; the other is a high boron stainless for reactor shielding and control rods. Both are introduced by the Universal-Cyclops Steel Corp.

The ideal stainless steel for nuclear applications should have no cobalt, but the complete elimination of this element is not feasible at present. Cobalt is an unwanted element because under irradiation it transforms to cobalt 60 which is a high gamma ray emitter harmful to human beings. Also, under high temperatures and corrosive conditions, the cobalt could be leached from the stainless steel and poison the nuclear system.

The second stainless steel has a high proportion of boron which is a neutron absorber, and therefore can be used to control the rate of operations within a reactor. The new high boron stainless steel (2 per cent natural boron) has a combination of physical and nuclear characteristics which are similar to hafnium, including high thermal neutron absorption, good structural stability, acceptable mechanical properties at 260 deg. C. under irradiation, and good corrosion resistance.

Metal Coating by Diffusion in Aerosols

The saturation of steel surfaces with such metals as aluminium, chromium, manganese and others in a gas which contains suspended particles in the solid phase is reported to have been achieved at the Soviet Central Scientific Research Institute for Mechanical Engineering and Production.

The equipment used in this process, based on ideas filed several years ago in a Russian patent, contains a reaction chamber in which the components are placed. A dosage device is connected, which during the first 10-15 min. of

heating fills the vessel at an increased rate with the reaction products of the working mixture to prevent oxidation of the component.

During the treatment, the dosage device feeds the working mixture in small portions every 1-2 min.

For an aluminising treatment, the active medium is a mixture of the finest aluminium powder and ammonium chloride. The aluminium powder ensures the chloride formation throughout the volume of the reaction chamber. Part of this powder is present in a suspended state within the gas phase, thus forming a kind of aerosol.

At a high temperature, the ammonium chloride evaporates and dissociates, forming hydrogen chloride, nitrogen and hydrogen. At a temperature below 300-400 deg. C. the hydrogen proceeds with the formation of ammonia and hydrogen chloride. This hydrogen chloride is the basic gas which takes part in subsequent reactions of chloriding of metals.

The chloriding of aluminium was studied by the Russian team in great detail alongside the chloriding of chromium, manganese, titanium, iron, nickel and molybdenum. It was found in these investigations, that the addition of sodium chloride has apparently a catalytic effect on the various reactions.

During the metal coating in aerosols, the metal powder exists inside the reaction chamber in a suspended state. However, special tests have proved that the diffusion activity of the medium is largely due to the vapour phase.

The recommended procedure for aluminising consists of introducing an active mixture of aluminium powder, sodium chloride and ammonium chloride in the ratio (by weight) of 4:2:1. An even higher activity is obtained with a ratio of 8:2:1.

For simultaneous saturation with aluminium and chromium, a mixture of aluminium powder, chromium powder, sodium chloride and ammonium chloride is recommended in the ratio of 2:2:1:1 or 4:4:2:1.

In chromium coating, several parts of ammonium chloride must be introduced for each part of chromium.

A forced circulation in the chamber is recommended. The re-introduction into the chamber of the escaping gas increases the depth of the aluminised layer. Aluminising for two hours has given satisfactory protective layers. When aluminising heat resisting alloys in aerosols, it is useful to combine the heat treatment with the aluminising process, and in this case aluminising is carried out at at least 1,050 deg. C.

Fibrous Metal Improves Filter

Mr. Morris Kilbrick, a metallurgist for Purolator Products Inc., has been selected by the U.S. magazine, *Materials in Design Engineering*, as the 1959 winner of its product design award. The award—"for imaginative and progressive use of engineering materials in product design"—was made for his design of a new fibrous porous metal filter disc.

In designing the high temperature metallic filter medium, traditionally made with porous metal powders, Kilbrick substituted stainless steel fibres. This product modification resulted in a porous filter medium with increased permeability, greater flexibility, and improved appearance.

The award-winning filter medium is designed for relatively low flow and high contaminant and/or product collection, with 10-micron filtration of corrosive solutions at temperatures up to 540 deg. C.

Now in production, the newly-designed fibrous porous metal filter disc measures $\frac{1}{16}$-in thick, 10 in. outside diameter, and 3 in. inside diameter, providing an effective filtering area of approximately 1 sq. ft. The disc is engineered for operations with wide temperature ranges, differential pressures to 200 p.s.i. plus, and is said to resist all effects of most concentrations of nitric acid.

Flexible Batteries for Submarine Cables

Snake-like batteries have been developed for the U.S. Army Signal Corps in powering submarine communications cable repeaters. Placed next to each transistorised repeater, they are spliced into the cable every mile to boost voice or teletype signals.

The flexible zinc-silver chloride batteries are activated when immersed in water. Their flexibility enables them to be wound on drums with the repeater units and cable. Their segmented construction consists of spool-shaped links of silver chloride separated by rubber rings from the zinc segments, and a wire which spirals the length of the battery connects the various sections.

The basic battery size is $\frac{1}{2}$ in. dia. and 30 in. long. They are reported to deliver 5 milliamperes continuously at 1 volt for a year. Operational life can be extended by using two or more of the batteries or by making them larger. They can also be built to any size, with a delivery rate of more than 40 watt-hr. per pound. Self-discharge (corrosion) in sea water is said to be negligible and they are claimed to have an infinite shelf life and activated stand life. The makers, Aerojet-General Corp., also say the batteries require no maintenance.

Heat Treatment in a Steam Atmosphere

Heat treatment of steel products in a steam atmosphere is recommended as a result of recent tests carried out first at Kharkov University and subsequently at the Zhdanov Tube Works in Russia.

Tests were carried out on specimens of 0·36 per cent carbon steel with 0·8 per cent manganese. Specimens were heated in an electric muffle furnace to various temperature levels between 400 and 1,000 deg. C. For comparison, identical specimens were heated similarly without steam atmosphere. Instead of the formation of scale flaking off locally when heated without steam, a dense oxide film with good adhesion was obtained in a steam atmosphere.

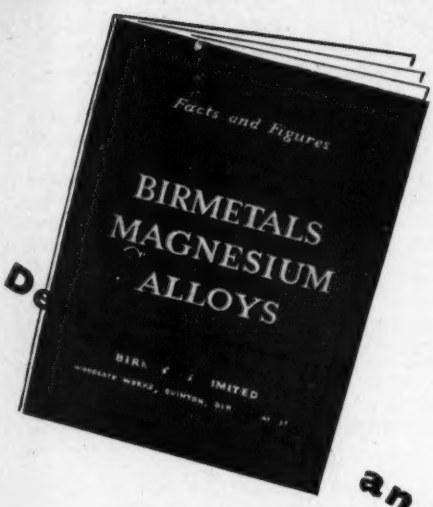
It was further found that dense oxide films obtained by soaking at 550 deg. C. in a steam-filled furnace constituted a good protection against the formation of scale in subsequent heating up to 1,000 deg. C. in an ordinary furnace.

Earlier tests had already established that samples heat treated in a steam atmosphere suffered no deterioration of mechanical properties.

High Temperature Plastics

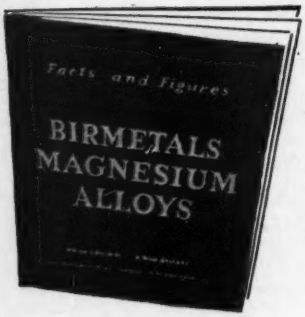
A new range of plastics materials for use at elevated temperatures has been developed which is expected to find wide application in many different spheres of industry. Produced by Haveg Industries Inc., they are marketed under the names of Rocketon, Missileon and Planeton II and IV. Each is said to be capable of working in temperatures up to 4700 deg. C. Planeton IV T and Q may be used in even higher temperature ranges.

Orbiton, the most recently-introduced product, is a combination of phenolic and nylon which may be laminated, pressure moulded and filament wound. It has a specific gravity of between 1·15 and 1·25 and a laminated tensile strength of 14,000 p.s.i. It is recommended for temperatures between 3000 and 9500 deg. C. No figures are at present available of its properties at these temperatures, although it has been used to a large extent in missile applications, and components as large as 5 ft. dia. × 6 ft. high have been moulded. Orbiton is an ablative type insulator, having the interesting characteristic of being approximately two-thirds the weight of glass-reinforced plastics.



an eye to the future

MAGNESIUM ALLOYS



Please send me booklet

Name .....

Position .....

Business address .....

.....

Is magnesium difficult to weld? Does magnesium corrode in the machine shop? Is magnesium difficult to bend or form?

All these questions, and indeed many more, are answered in this new booklet, which also contains full details of the mechanical properties of magnesium alloys in all wrought forms.

Your reference file is incomplete without this very informative publication. Send for your copy today.

Birmetals

BIRMETALS LIMITED
WOODGATE WORKS
BIRMINGHAM 32

BM 212

New Books

Nuclear Reactor Physics. *By Raymond L. Murray* (*Macmillan, 30s.*).

A TEXT-BOOK on reactor theory, combining a straightforward presentation with an adequate number of numerical examples, has been needed for some time. Therefore, this book, written by Prof. Murray, consultant on reactor design at Oak Ridge, must cause considerable interest.

The book opens with a description of nuclear fission and the various types of reactor. The next chapters on neutron motion and one-group theory give the reader a feel of the type of solution required, and then the concepts of thermal utilisation, resonance escape probability and fast fission factors are introduced to develop the more useful two-group theory. The variation of reactor power with time is discussed and an analysis follows of the factors like temperature, burn-up and xenon poisoning which alter the reactivity. The more complex ideas of transport theory and multi-group methods are dealt with separately.

A general impression of clear, concise writing allied to numerous worked examples makes this an excellent book to recommend as an introduction to the subject. Post-graduate and undergraduate students will both find the many examples in each chapter useful exercises, while the more experienced engineer or scientist will welcome the comprehensive lists of references. K.A.W.

Fluctuation Phenomena in Semiconductors. *By A. van der Ziel* (*Butterworth, 35s.*).

This is a comprehensive survey in which the author has drawn considerably from his own work and from that of his colleagues and research students at the University of Minnesota. He has, however, shown a good sense of balance in integrating the work of the many other contributors to this field; each chapter contains an adequate list of references.

The main topics treated are generation-recombination (including shot) noise and flicker noise, in both materials and devices. These are well done. Surprisingly, there is no basic treatment of Johnson noise; this may cause some confusion to the uninitiated reader. At present there is no standardisation of nomenclature with regard to the different sources of noise. Unfortunately, the author's suggestions in Chapter 1 do not seem to clarify matters. These are minor shortcomings, however, and do little to detract from the usefulness of the book. It will be particularly valuable to the reader with a direct interest in some aspect of semiconductor noise. F.J.H.

The Heat Treatment of Steel (*Pitman, 35s.*); **The Structure of Steel** (*Odhams, 18s.*). *By Edwin Gregory and Eric N. Simons.*

The chapters of this second edition of the volume on steel heat treatment have been rearranged to provide a more logical form of presentation, and new information dealing with austempering, martempering and sub-zero treatment has been added. Designers, engineers and students requiring to know the application, the control and the effects of heat treatment will find much to appeal to them in this book. To obtain most benefit, it should be read in conjunction with *The Structure of Steel*, which discusses in straightforward terms the constituents of iron-carbon alloys, crystalline structure, impurities, structural and mechanical properties. Further chapters deal with testing materials, heat-treatment processes and the effects of mechanical working. An appendix contains tables of hardness values, a glossary of terms and a useful bibliography.

The Manufacture of Iron and Steel: Vol. 2—Steel Production. *By G. Reginald Bashforth* (*Chapman & Hall, 40s.*).

Rapid strides in the production technology of steel have made the appearance of the second edition of this book timely to keep the student or industrialist reader up to date. To accommodate the section previously dealing with fuels, refractories and instruments—and which has been considerably extended—a third volume of this series is to be published in the near future.

In this present volume a careful balance has been kept between processing and complex metallurgy, sufficient chemistry being included to indicate the nature of the reactions taking place. The efficiency and the cycles of the various processes are thoughtfully presented and the illustrations are practical and useful in understanding some of the complexities in steel making.

Electric furnaces are fully dealt with, as are the newer oxygen-enrichment techniques, including the Kaldo, Rotor and L/D processes. The chapter on the manufacture of some types of special steel is of interest, particularly in relation to continuous casting. The final chapter deals briefly with physical chemistry and thermodynamics. Even if one has only a passing interest in the manufacture of steel, this book will absorb the reader to the end and, because it is factual and right up to date, he will benefit from it.

Laminated Plastics. *By D. Duffin* (*Chapman & Hall, 46s.*).

This book by an American, writing about laminated plastics as manufactured and used in the U.S.A., could equally apply to this industry in the U.K. Mr. Duffin explains the difficulties of the uninitiated in trying to untangle the mass of trade names and varying terms as used by trade journals and magazines to describe what are and should be called laminated plastics. How well this applies to this country.

This comprehensive book covers all aspects of the industry with chapters on the chemistry of resin, the material make-up, manufacturing processes, machining, heat resistance and other laminates, besides other essential chapters dealing with grading, characteristics, applications and end products.

From the fabricator's point of view the chapter on machining is precise, though more detail could, perhaps, have been given to individual operations. But there is also an immense amount of general information useful to designers.

The most up-to-date information is given, with emphasis on the heat-resistant laminates. The book is well arranged and makes easy and interesting reading. B.R.L.

Proceedings of the 1956 Conference on Thorium. (*American Society for Metals. $10*).

This contains much valuable data for the engineering designer as well as for the nuclear physicist or research metallurgist. Apart from its nuclear application as a fuel element, thorium is used principally as an alloying agent, and the chapter dealing with its use in magnesium alloys contains a wealth of detail on mechanical properties. There is also useful information on the fabrication and machining of pure thorium.

Symposium on Strain Gauges. (*A.S.M.E. Spec. Tech. Pub. No. 230, $4.50*).

One of the limitations of strain gauges, which are used increasingly for ascertaining stresses in mechanisms and structures, has been the lack of consistency and reliability at elevated temperatures. The proceedings of this recent symposium include a great deal of valuable information on gauges operating under these conditions.

Automatic Measurement of Quality in Process Plants. *Proceedings of 1957 Conference sponsored by Society of Instrument Technology* (*Butterworth, 50s.*).

The papers provide a wide and objective introduction to methods of quality control which may be applied to process plants with the emphasis on automatic measurement. In fact, the methods covered can be taken to be the initial stages and will ultimately lead to completely automatic control of complex chemical plant.

Among new standards recently issued by the B.S.I. are:

B.S. 3111:1959. Steel wire for cold-forged high-tensile bolts and similar components (4s. 6d.).

B.S. 2970:1959. Magnesium and magnesium alloy ingots and castings for general engineering purposes (8s. 6d.).

B.S. 1407: 1959. High-carbon bright steel (silver steel) (4s.).

B.S. 3064: 1959. Sine bars and sine tables, excluding compound tables (4s. 6d.).

B.S. 3082: 1959. Mechanical testing of steel at elevated temps. Pt. 1. Determination of proof stress (3s.).

B.S. 3071: 1959. Nickel copper alloy castings (4s.).

HIDUMINIUM 100 (S.A.P.)

Engineering Materials and Design
DATA SHEET No. 22

Specific gravity: 2·8 Density: 0·101 lb./in.³

SHEET (nominal oxide content, 10%—values taken for 16 s.w.g.)

Thermal expansion coefficient:

20-100°C.	20·0 × 10⁻⁶
20-200°C.	21·0 × 10⁻⁶
20-300°C.	21·5 × 10⁻⁶
20-400°C.	22·0 × 10⁻⁶

Thermal conductivity, c.g.s. units: 0·435

Ultimate tensile strength:

longitudinal	53,100 p.s.i.
transverse	55,500 p.s.i.

0·1% proof stress:

longitudinal	33,800 p.s.i.
transverse	35,600 p.s.i.

Mechanical properties are given for room temperature.

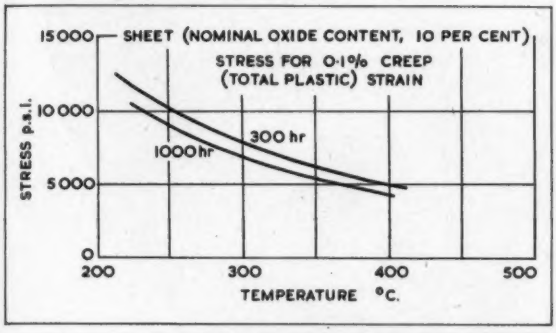
Specific resistivity: 4·5 microhm-cm.

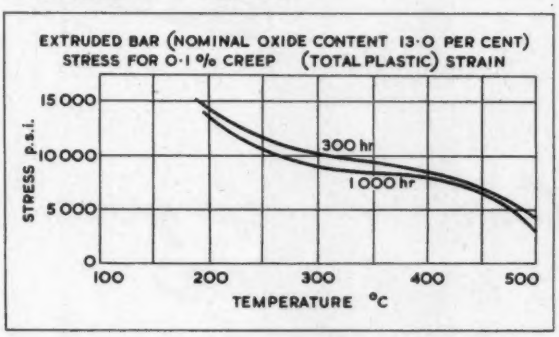
EXTRUDED BAR (nominal oxide content, 13%)

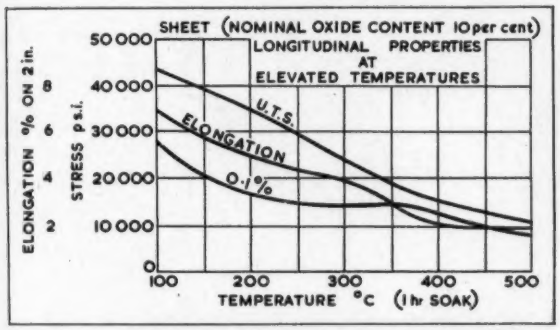
Thermal expansion coefficient:

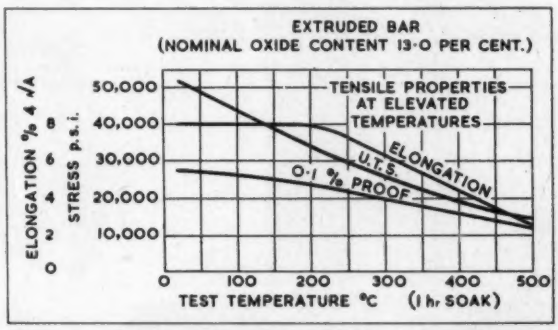
20-100°C.	19·5 × 10⁻⁶
20-200°C.	20·5 × 10⁻⁶
20-300°C.	21·3 × 10⁻⁶
20-400°C.	21·8 × 10⁻⁶

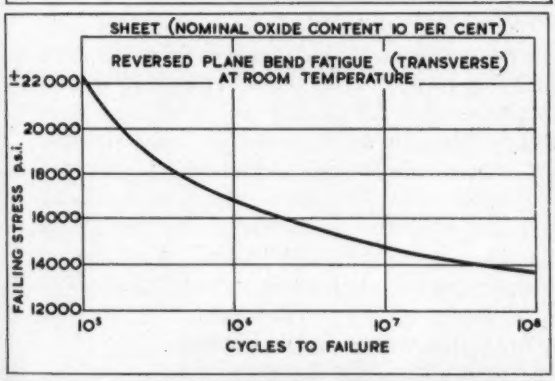
Thermal conductivity, c.g.s. units: 0·4
Ultimate tensile strength: 52,900 p.s.i.
0·1% proof stress: 27,400 p.s.i.
Elongation, % 4√A 8
Young's modulus: 11·3 × 10⁶ p.s.i.
Modulus of rigidity: 4·2-4·3 × 10⁶ p.s.i.
Basic shear stress: 32,500 p.s.i.

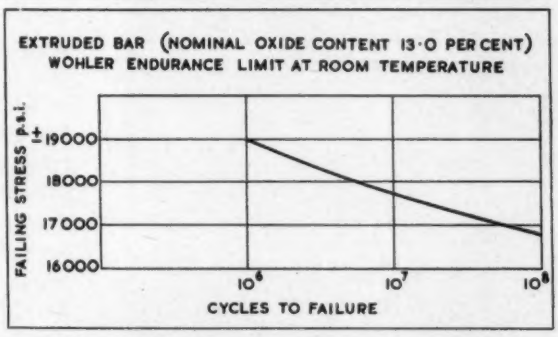


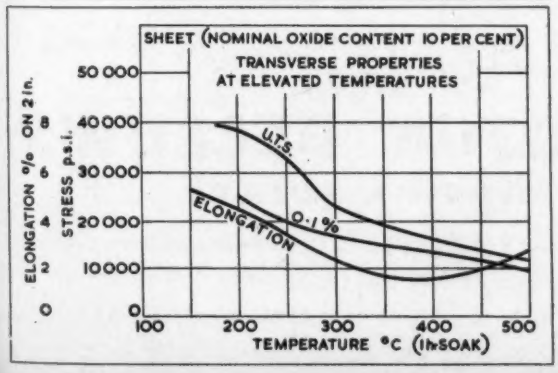


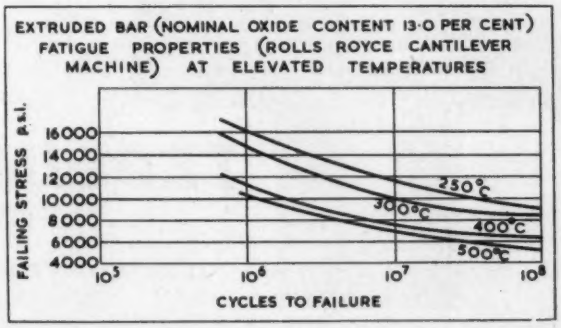












Data by High Duty Alloys Ltd.

EMD 1491 for further information

Can we help you with your pipe problems?

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

SEND FOR BROCHURE No. X107

Teddington Bellows are produced in technical collaboration with the Solar Aircraft Co., U.S.A.

TEDDINGTON BELLOWS

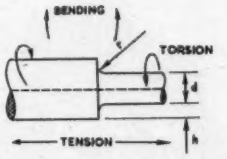
EXPANSION JOINTS

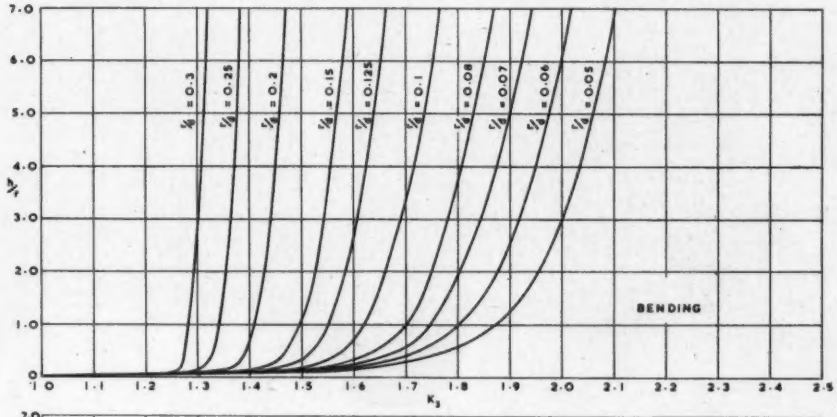
TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255

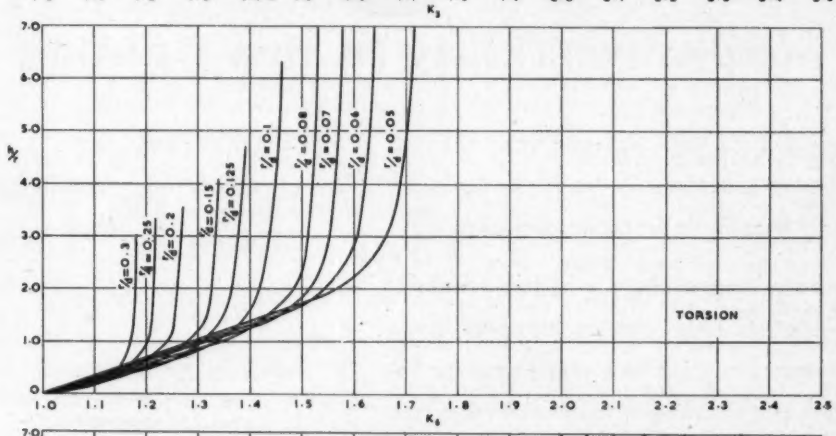
STRESS CONCENTRATION FACTORS FOR A SHOULDER ON A CIRCULAR SHAFT

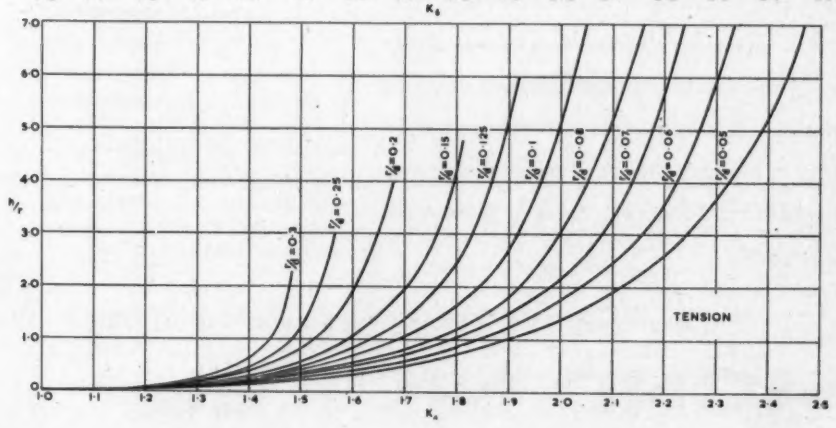
Engineering Materials and Design
DATA SHEET No. 23

Abrupt variations of stress distribution due to a change in a cross-sectional area cause stress concentrations. The following factors are given for conditions of bending, torsion and tension loads, and are a measure of the increased local stress.









Data Sheet by H. Vincent, B.Sc., A.F.R.Ae.S.

EMD 1492 for further information

NICKEL ALLOY STEELS

ensure reliability in fire fighting appliances

Long days of relative calm interspersed with short bursts of furious activity provide the continuing test of reliability for fire fighting appliances.

Into the design of the fire fighting vehicles of Dennis Bros. Ltd., Guildford, have gone decades of experience which have taught them the importance of specifying materials which will not fail. In the appliances are nine nickel alloy steels, notably the nickel-chromium case-hardening steel EN 36, which is used for the gear box gears and for engine components. By such thoughtful measures, equipment breakdowns and resultant disasters are alike avoided.

Typical core mechanical properties of 3 per cent nickel-chromium steel

EN36

ARE GIVEN BELOW:

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
1½" dia.	Oil quenched 780°C.	72·0	19	69
2½" dia.	Oil quenched 860°C. Oil quenched 780°C.	62·7	19	67
3" dia.	Oil quenched 860°C. Oil quenched 780°C.	59·7	22	72

The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33; EN 34; EN 36 and EN 39 include ease of heat treatment, minimisation of processing distortion, higher load-carrying capacity, and general reliability.

Send for 'The Mechanical Properties of Nickel Alloy Steels' ▶

TGA 21/25

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, S.W.1

ON SHOW AT FARNBOROUGH

The Society of British Aircraft Constructors has just held its twentieth annual display and exhibition at Farnborough. Here is a review of some of the exhibits

H.T.P. Fuel

Laporte Industries Ltd., exhibiting for the first time at this show, devoted one of three stands to high-test hydrogen peroxide (H.T.P.), and a typical small rocket motor was shown working on this fuel. Also featured were organic peroxides for use as initiation catalysts for the polymerisation of certain plastics, and the Metklens range of A.I.D.-approved metal cleaning compounds. A 600-gal. H.T.P. road tanker and a 500-gal. demountable shipping tank were also shown.

EMD 1558 for further information

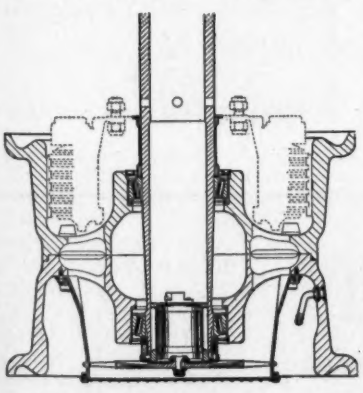
Power Tools

Four new portable pneumatic power tools shown by Desoutter Bros. were the reversible screwdriver powered by the Super Atom motor, a corner screwdriver and nutrunner supplied in two forms either with a ¼-in collet or with a ¼-in. square drive, a reversible corner nutrunner which can locate on nuts to within 1⅛ in. of a corner, and the Super Rotor grinder available as either collet or spindle type running at 16,000-18,000 r.p.m. This latter tool was being shown for the first time, the other three tools having been first announced earlier this year.

EMD 1559 for further information

Brake Fan

Undercarriage design and space limitations on modern aircraft have made it necessary to enclose most of the heat sink contained within the wheel, so that virtually no natural ventilation is possible. The Dunlop Rubber Co. Ltd. were showing for the first time a small ducted fan driven by an f.h.p. motor fitted within the hub. In addition to reducing the time for cooling after application of the brake, it also prevents



overheating of brake fluid and seals. Other new equipment shown were collapsible rubberised fabric containers which enable aircraft to carry liquids without modification to the cargo compartment, the containers being rolled up when empty for the return journey. Seen also for the first time is a new range of four compressors for ground charging pneumatic systems.

EMD 1560 for further information

Distance Meter

The Wayne Kerr distance meter D.M. 100 operates in conjunction with non-contacting probes to provides a basically linear method of measuring distance from 50 micro-in. to 0·5 in. The distance is read directly from a moving coil meter, the full scale range depending on which of the four available probes are in use. Readings are accurate to ±2 per cent of full-scale deflection and the discrimination is better than 0·5 per cent of full-scale readings. The instrument can be used for measuring distance in precision grinding processes and can be adapted for use in the dynamical balance of helicopter blades and the measurement of verticality of control rods in reactors. The design is centred on a high-gain amplifier with a negative feedback loop completed by the capacitance between the probe and test structure.

EMD 1561 for further information

Heating Element

Sierracote, marketed in this country by D. Napier & Son Ltd., is a transparent conductive coating used for heating aircraft windscreens and cockpit canopies when de-icing or demisting is required. The heating element is a metallic coating which is applied by evaporation in a high vacuum. It is applicable to glass and all plastics materials used for canopies, and it may be formed to shape either before or after the coating is applied.

EMD 1562 for further information

Metal Filter

A product entirely new to this country is the Bendix metallic filter media for use in high-pressure hydraulic filters exhibited by Vokes Ltd. and their subsidiary company, Stream-Line Filters Ltd. Known as the Poromesh and Poroloy, these media show great strength and rigidity, and are capable of withstanding a relatively high pressure differential over a wide range of operating temperatures. Among the wide range of filters made by these companies were included the Absolute 44 developed for tobacco smoke removal, cabin air recirculation, filtration and where radioactive dust is encountered. Other filters are for high-temperature air, oil vapour mist, fuel and oil filtration. In the larger sizes were included test-bed filters, among them being the K600 Komac which can be arranged into banks of any desired capacity.

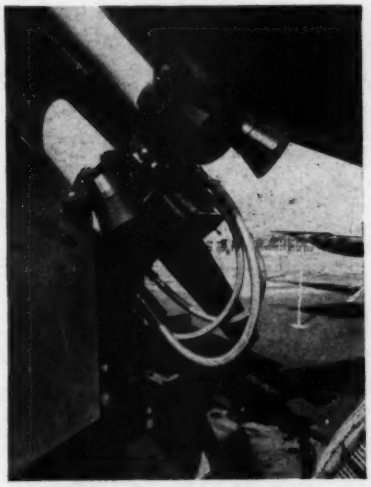
EMD 1563 for further information

Glass Fibre

Shown for the first time on the stand of Turner Brothers Asbestos Co. Ltd. was a range of p.t.f.e. products. There were also a number of examples moulded from Durestos (an intimate blend of asbestos and thermosetting resins) and Duraglas (which consists of glass-fibre materials used as a plastics reinforcement). The Duraglas exhibits include a complete series of mechanically- and chemically-bound chopped glass-fibre mats which are supplied under the name Duramat.

EMD 1564 for further information

Radio Test Equipment



Plessiflex metallic hose on a Bloodhound guided missile installation.

One of the most interesting exhibits shown on the stand of the Electronic and Equipment Group of The Plessey Co. Ltd. was a set of test equipment developed for the ARC-52 transmitter receiver, which provides amplitude-modulated radio-telephone communication in the 225-399 Mc/s band. The test equipment provides three progressive functions: first, to test the ARC-52 as a complete unit; second, if the first test indicates a fault, to discover in which module or modules it lies; third, to locate the fault in the individual module.

EMD 1565 for further information

Polyurethane Lacquer

Precision Rubbers Ltd. were showing a wide range of rubber aircraft components including those made from materials based on the fluoro-carbon rubber, Viton, and rubbers resistant to Skydrol 500 hydraulic fluid. Also of interest was a polyurethane lacquer which produces a film possessing many similar characteristics to their Prescollan, particularly the outstanding resistance to abrasion, tearing and rain erosion (the latter being more associated with radomes). The newly developed Prescolastik silicone rubbers are of particular note and are available in many grades to suit the most exacting conditions.

EMD 1566 for further information

EMD 1493 for further information

*PERMANENT PROTECTION
*LOWER PRESSURE LOSS
*NON-COLLAPSIBLE

AUTO-KLEAN
answers your filtration problems

AUTO-KLEAN LOLOS
wire-wound filters are extremely robust and give continuous defined mesh protection throughout the life of the plant to which they are fitted. They combine high flows with the minimum pressure loss, ensuring the greatest degree of filtering efficiency.

AUTO-KLEAN LOLOS
are supplied in a range of single and multi-element filters for flows up to 40,000 gallons per hour, and as duplex filters or build-in filter elements.

AUTO-KLEAN
FILTER ANYTHING THAT FLOWS.

* For micronic filtration with great strength specify AUTO-KLEAN LOLOS LF filters, consisting of a close-fitting fabric sleeve on a wire-wound element of .0008" mesh.

AUTO-KLEAN

AUTO-KLEAN STRAINERS LIMITED
LASCAR WORKS HOUNSLOW MIDDLESEX

ENGINEERS IN FILTRATION
Tel: HOUnslow 7722 (10 lines)

AUTO-KLEAN · AUTO-KLEAN MICOM · AUTO-KLEAN FLUSHFLO
AUTO-KLEAN CIRCO
AUTO-KLEAN LOLOS
AUTO-KLEAN KOTON
AUTO-KLEAN WYMESH

WHAT'S NEW IN MATERIALS & COMPONENTS

New Fluorocarbon Resin

A new engineering plastics known as Fluorosint was recently announced. It consists of p.t.f.e. and other specially-developed constituents intended to improve the mechanical and thermal properties of p.t.f.e. without affecting its unique electrical and chemical characteristics. The coefficient of thermal expansion is said to be about one-sixth that of p.t.f.e. and is therefore similar to that of a number of metals, thus solving problems of fits and clearances on thermal cycling. It is claimed that the dimensional tolerances of parts made in this material can be held far closer than with p.t.f.e. and, being free from stresses, no distortion is said to occur on thermal shock or temperature cycling. Hardness is also said to be increased and cold flow greatly reduced. Bearing and wear characteristics are also said to be a marked improvement over p.t.f.e. so that bearings made from this new material can be operated at much higher speeds and loads. Polypenco Ltd.

EMD 1567 for further information

Self-adhesive Urethane Foam

A self-adhesive foam material said to have many uses as gaskets, sealing strips and seatings is now on the market. The urethane foam is bonded to p.v.c. strip carrying the adhesive, which is in turn protected by a corrugated p.v.c. backing.

The material is available in a variety of thicknesses and in widths from ¼ in. to 18½ in. For engineering purposes the ratio of compression to density of the foam may be of special interest. The elasticity is lower than latex and recovery is slow, and this is said to make it suitable for soft cushioning and damping of vibration. The foam material is said to be non-toxic and will not support fungus, vermin or insect life. It will not hold water and is said not to show any wicking action. A special heat-resistant variety is available for sealing applications where comparatively high air temperatures are expected. The material is said to be electrostatically neutral, and therefore does not attract dust and other airborne particles. Sealdraught Ltd.

EMD 1568 for further information

Wood Neutron Shielding

Jabroc N is a densified wood made in laminations from beech veneers interleaved with glue film and compressed under heat and pressure. It is available in densities from 84 lb./cu. ft. upwards, the higher density materials being loaded with additives such as boron carbide. The 84 lb./cu. ft. material is said to give a relaxation length for fast neutrons of 7·8 cm. Special grades are also available with increased fire resistance. For criticality shielding, where neutron capture is required, grades with boron or rare earth additions are used, and these additives may be dispersed throughout the material or concentrated at one surface. Compared to concrete, this material is claimed to have the advantage of cheaper and less elaborate mechanical support and to be easier to handle where movable shielding is required. Compared to natural wood, it is said that only half the thickness is required to offer equivalent shielding. Permali Ltd.

EMD 1569 for further information

Silicon Carbide

G.R.B. silicon carbide, now available in this country, is a dense self-bonded silicon carbide body having a high free-carbon content in granule form. Its composition is 50-78 per cent silicon carbide, 20-46 per cent free carbon and 1-3 per cent free silicon. The properties can be varied by altering the composition, but the shock and erosion resistance are claimed to be excellent over the full range of compositions. This is said to be due to the fact that the dense silicon carbide matrix provides a protective shield around the graphite particles, thus preventing rapid oxidation and erosion. Under high thermal shock conditions, however, the graphite particles are said to absorb the uneven expansions, thus preventing high stress concentrations and failure. The Carborundum Co. Ltd.

EMD 1570 for further information

High Flash Etch Primer

A new finishing material for metal, known as Celletch, with a flash point over 32 deg. C. is now available. It is a two-part solution, the primer requiring mixing with an equal volume of reducer to provide a pot life of eight hours and a drying time of about one hour. The primer is chromate yellow-green in colour and is said to be water resistant and to show good ahesion to zinc-coated sheets as well as to steel and aluminium. Cellon Ltd.

EMD 1571 for further information

Permanent Magnets

The Magloy range of cast permanent magnets is now available to British industry. They are precipitation-hardened alloys which are said to enable precision-cast magnets even in small sizes to be produced to relatively close tolerances. The provision of aluminium jackets for mounting and protection purposes gives protection against magnetic damage. It is claimed that the magnets are highly resistant to shock and vibration at any frequency and that they are extremely stable to demagnetising influences. The magnets are given a controlled heat treatment which is said to render them stable up to 500 deg. C. Preformations Ltd.

EMD 1572 for further information

Plastic Foam

Foamedge is a new edge-sealing strip made of polyurethane foam covered with p.v.c. It is manufactured in a variety of sizes from ¼-1in. in diameter and is recommended for sealing of wooden- or metal-framed apertures against draught, dust or heat. Lintafoam (Sales) Ltd.

EMD 1573 for further information

New Titanium Grades

Four new materials have been added to the production range of wrought titanium and titanium alloys available in this country. They comprise two additional grades of commercially pure titanium (known at titanium 125 and 150) and two alloys (titanium 230 and 679). The commercially pure grades are expected to give more latitude to the fabricator of assemblies, such as vessel linings and pipework for chemical plant, in which ductility is a prime factor, while improvements in formability of the harder grades will permit their use for more highly stressed components. The alloy, titanium 230, has been developed for applications, mainly in the aircraft industry, where medium strength at moderate temperature must be combined with good weldability and formability. Titanium 679 is designed to withstand high stresses above 400 deg. C., and is intended for aero engine components. I.C.I. Metals Divisions.

EMD 1574 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Flame-retardant Polyethylene

A new development of polyethylene, which is said to make it self-extinguishing and to prevent propagation of combustion, is the blending of polyethylene with boron-chloro-oxide derivatives. Believed to be the first British manufacture of this material two grades are available, standard with a softening point of 88 deg. C. and heavy duty which softens at 92 deg. C. The former is said to have applications in household wiring, telephone and switchboard wiring, and the latter for power cables, high-voltage electronic or outdoor cables. C. J. W. Macaulay.

EMD 1575 for further information

Lamination Adhesive

Bondmaster L379 is a strong, flexible, solvent-resistant adhesive specially formulated for laminating polyester film to resin-impregnated asbestos papers, kraft papers, rag papers, varnished fabrics and papers, and similar electrical insulating materials. These laminations are used as phase and layer insulation in electric motors, generators and transformers. It is claimed to have superior resistance to organic solvents and hot oils. It is also said to have excellent resistance to heat-ageing, passing Class B insulation heat-ageing tests such as 96 hr. at 125 deg. C. Omni (London) Ltd.

EMD 1576 for further information

Plastics Tooling Compound

Kollercast plastics tooling compounds are based on epoxy resins and are formulated for the manufacture of plastics tools by simple methods and with the minimum of special equipment. Intended to be handled by engineers, these products are supplied as a two-pack system, one component being the epoxy-based compound and the other being a curing agent. In most cases both components are liquids to facilitate mixing and the curing agent is usually based on special polyamide resins which are claimed to be easy and safe to handle, while giving excellent toughness to the finished product.

Fillers and pigments are already incorporated in the materials as supplied and no weighing is required, equal volumes of compound and hardener being used. A two-colour system is used for the ingredients, so that it can be readily seen when mixing is complete (see illustration below). Beck, Koller & Co. Ltd.

EMD 1577 for further information

Rubber Conveyor Belting

The Numec belt is constructed of rubber and canvas, the number of plies being dependent on the load-carrying requirements. A full range of belt widths is available. The speciality of this belt is that running both sides full length is a patented corrugated rib. The object of this is to increase the capacity of a conveyor by 50 per cent and also to increase the permissible inclination by between 10 and 25 per cent, depending on the materials.

A further feature is that running at right angles to the centre line of the conveyor are moulded rubber flights, and with these a further increase in inclination is said to be possible. It is claimed that with this belting, which can handle both bulk and packaged materials, equipment to suit special loads is not required. Numec Ltd.

EMD 1578 for further information

Skydrol-resistant Rubber

Skydrol 500, a phosphate ester-based fluid developed as a fire-resistant hydraulic fluid for aircraft, has presented the rubber technologist with the problem of finding a suitable elastomeric compound to use as a seal. The majority of rubbers are severely attacked by Skydrol fluid, and butyl has provided the most satisfactory answer. A product called Grade X213X is said to have been tested and approved by the Douglas Aircraft Co. in co-operation with Monsanto Chemicals Ltd. in London. The compound is claimed to have a tensile strength of over 2,000 p.s.i. and the volume change in Skydrol 500 fluid at 70 deg. C. is said to be less than 5 per cent and at 100 deg. C. approx. 15 per cent. The low-temperature properties of the product are said to be good and a torsion modulus of 10,000 p.s.i. is not reached until −45 deg. C. Good compression recovery is claimed. Precision Rubbers Ltd.

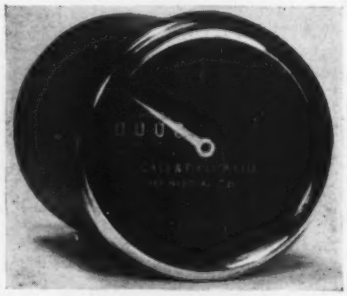
EMD 1579 for further information

Foam Cable Casing

To meet special requirements for cables with lower attenuation, lower capacity, lower cost and lighter weight than standard cables, a new and versatile dielectric material for cable casing has been introduced with the name of Polyfoam. It is a cellular polyethylene which utilises an inert gas as an expanding agent to form completely enclosed cells. Polyfoam is said to have a dielectric constant of 1·50 as compared with 2·25 for solid polyethylene, and to provide less attenuation. It has a specially compounded non-contaminating black polyethylene jacket providing improved weathering properties and abrasion resistance. For greater shielding effectiveness, where radiation presents a problem, Polyfoam triaxial cable is available, having an added full coverage shield and jacket. Amphenol (Great Britain) Ltd.

EMD 1580 for further information

Elapsed Time Indicator



This is an instrument which registers the true operating hours of a vehicle or machine and can be used for assessing maintenance requirements. The new unit is completely sealed and insulated, being designed with a double-skin case, the mechanism being mounted on beryllium copper leaf springs. The balance staff, balance wheel and armature assembly are jewel-mounted and of rugged construction. The inner case is of polyethylene and the outer one of steel, so that the unit is completely sealed from ingress of water and the movement is electrically insulated from the case. Elapsed time can be read in hours and minutes to the nearest 15 sec. and timing accuracy is said to be better than 15 secs in 24 hr. Cass & Phillip Ltd.

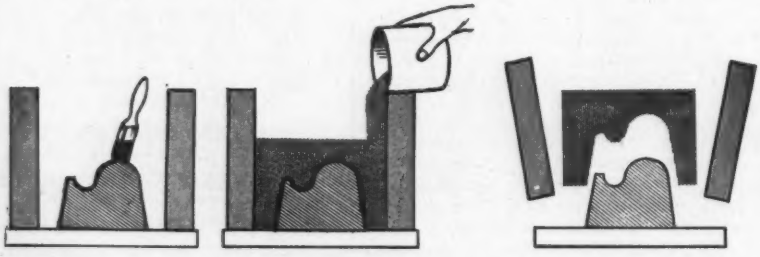
EMD 1581 for further information

Chromate Conversion Coatings

A new range of chromate conversion coatings, known as Tridur, has been introduced for zinc, cadmium, aluminium and magnesium. They range from transparent and colourless coatings on zinc and cadmium to coatings which, except for magnesium, may be dyed a variety of colours for identification purposes. The basic advantage claimed for the coatings is exceptional corrosion resistance. For example, that on aluminium is said to be close to that afforded by anodising, but at a fraction of the cost.

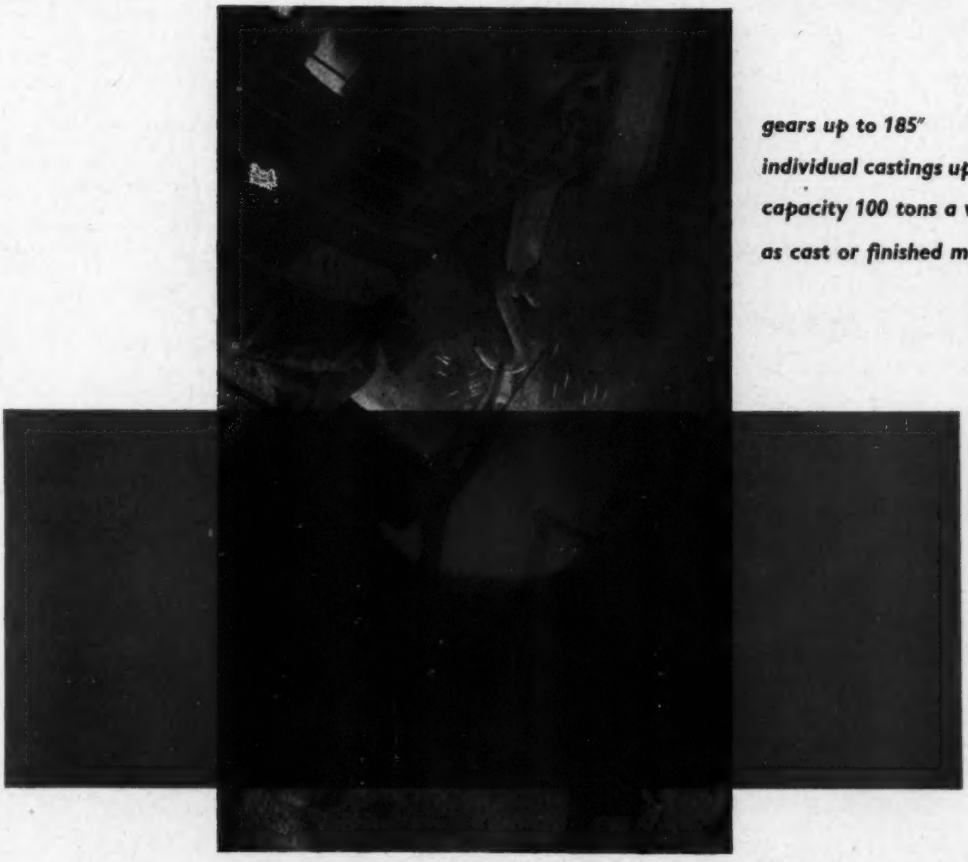
Additional features claimed are brilliant or transparent coatings preserving the original decorative appearance of zinc and cadmium (also yellow and green coatings), and the solutions are non-electrolytic, non-fuming, and work at room temperature. Components are treated very rapidly by simple immersion. Roto-Finish Ltd.

EMD 1582 for further information



EMD 1494 for further information

when it calls for steel castings . . .



gears up to 185"
individual castings up to 7 tons
capacity 100 tons a week
as cast or finished machined

. . . call for Crofts of Bradford

makers of: *Clutches, Conveyor Drives, Couplings of all types, Double helical gear units, Fabricated steelwork, Geared motors, Hydraulic couplings, Iron, steel and non-ferrous castings, Machine-cut gears of all types, Motorised rollers, Patent Taper-flush-bushes, Plummer blocks, Shaft-mounted gear units, Special machinery drives, Spiral bevel gear units, Turbine gears, V-Rope Drives, Variable speed drives, Worm reduction gears.*

no modern design department should be without a comprehensive set of Crofts Technical Publications Bona fide requests will be dealt with promptly by our Publicity Department at Bradford, or by any of the Branch Offices at: Belfast, Birmingham, Bristol, Cardiff, Dublin, Glasgow, Ipswich, Leeds, Liverpool, London, Manchester, Newcastle, Northampton, Nottingham, Sheffield, Stoke-on-Trent

CROFTS (ENGINEERS) LIMITED

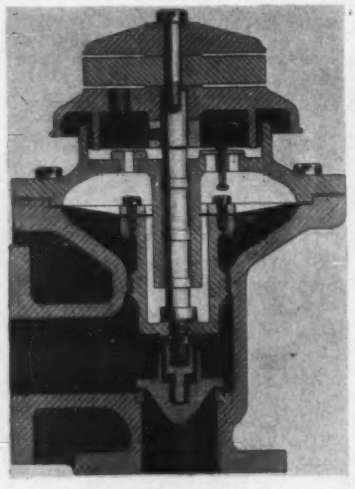
POWER TRANSMISSION ENGINEERS

Head Office: Thornbury Bradford 3 Yorkshire

Telephone: 65251 (20 lines) Telegrams: "Crofters Bradford Telex" Telex 51186

Relief Valve

A novel type of pressure-relief valve has been designed to overcome some of the difficulties inherent in orthodox relief valves which have to operate under corrosive conditions. The valve incorporates a diaphragm (which can be supplied in p.t.f.e.) which is to retain an oil seal around the vertical spindle bearing, designed in such a way as to prevent any possibility of corrosive vapours affecting



the bearing. A further feature is that on the occasion when the valve lifts, the oil is displaced rapidly at a high rate of flow, thus enabling the valve to lift to its full extent very rapidly. After release of pressure a dash-pot arrangement comes into play and this causes the valve to float comparatively slowly on to its seat, thus, it is said, maintaining the valve and seat in good condition for long periods. Robert Harlow & Son Ltd.

EMD 1583 for further information

Polyether Resin

Daltolac 41 is a new polyether resin specially designed for use with Suprasec D to produce rigid polyurethane foams by the spray process. The low-density (3-5 lb./cu. ft.) foams are said to show excellent thermal insulation properties and to have very good resistance to water uptake and water vapour transmission. For many applications, these foams are claimed to offer substantial economic and technical advantages over conventional insulation techniques. Special equipment is now available commercially for spraying the foams, which are expected to find extensive use for spraying thermal insulation on open surfaces. I.C.I. Dyestuffs Division.

EMD 1584 for further information

Polycarbonate

The German polycarbonate Makrolon is now available in this country in the form of injection moulding and extrusion compound. The outstanding properties claimed for this material are good impact strength at high and low temperatures, heat resistance up to 135 deg. C., cold resistance down to −100 deg. C., low water absorption and excellent dimensional stability and good resistance to acids, oxidants, oils and petroleum hydrocarbons. Although hard and rigid, this material nevertheless possesses high resilience and it is expected to find application in a wide range of engineering applications. R. H. Cole & Co. Ltd.

EMD 1585 for further information

Plummer Blocks

The Fenner-Dodge SC ball-bearing plummer blocks were recently introduced to meet the demand for a practical precision-built anti-friction bearing for shafts up to 2½ in. in diameter to carry moderate loads. The housing offers pleasing appearance combined with great strength, and full alignment is provided by a spherical outer race of the ball bearing which fits accurately into the spherical seat in a high-grade cast-iron housing. The bearings are sealed to exclude dust and dirt and to retain lubricant, but it is claimed that the seals cannot be blown out when using a grease gun. A separate collar is provided to locate the bearing on its shaft without causing distortion of the inner race. J. H. Fenner & Co. Ltd.

EMD 1586 for further information

Drive Unit

A range of gear units has been designed specially to suit agitators and mixers, whereby it is possible to change speed over a very wide range by "pick-off" gear assembly. Horsepower ratings are available for any desired output speed, calculated in accordance with the capacity of the gears, heat-dissipating capacity of the cases and churning losses. Dry well construction on the final shaft is said to eliminate oil leaks. The final reduction is by worm gearing designed to give high load capacity with inherent, silent and smooth operation, together with simplicity in mounting, which is important for maintenance. Three sizes are at present available up to 62 h.p. Highfield Gear & Engineering Co. Ltd.

EMD 1587 for further information

Air Control Valves

A new range of piston-type air control valves has recently been introduced. These valves are claimed to overcome the main objections to piston valves in that they neither use reciprocating O-rings on the piston nor depend on a "micro" metal-to-metal fit between piston and body. The actual piston unit is interchangeable and inexpensive and, as this is the only wearing component in the valve apart from the static seals, this valve can be easily serviced without removing the body from the air line. This particular design of piston valve is said to have the advantage of operating under very light pressure, without being less positive. It is made in ¼ and ⅜ B.S.P. Air Automation.

EMD 1588 for further information

Digital Voltmeter

The digital voltmeter type LM 902 has been designed for the foolproof monitoring of physical quantities converted into voltages electronically to four figures. The instrument is claimed to eliminate completely all error factors of conventional meters, besides performing many added functions and providing easy-to-read figures. There are five voltage ranges with an accuracy claimed to be better than 0·1 per cent. Solartron Electronic Group Ltd.

EMD 1589 for further information

Pneumatic Speed Regulator

A new and improved speed regulator, capable of giving more control over flow than the earlier model, has just been announced. The regulators are made in four sizes, ranging from ¼ to 1 in. B.S.P. and are manufactured in aluminium alloy and anodised. Among the features claimed for these components are absence of sealing parts to wear, no extra pipe fitting required, as they screw directly into the exhaust port of the control valve, and a friction device to prevent vibration from altering the control setting. Baldwin Industrial Co. Ltd.

EMD 1590 for further information

Small Electric Motors

An additional range of small electric motor units has recently been introduced. They are available geared or gearless, the geared motors giving a range of final shaft speeds from 28 min. per rev. to 562 r.p.m. for continuous or intermittent operation, while the gearless motor runs at 2,700 r.p.m. light. The types available are RQR (illustrated) with gear train for continuous running and reversing, and valves and dampers; RQ53, similar to RQR but for heavier duty; RQU, for the operation of valves and dampers; and RQH, for continuous running at higher speeds and light duties. The gearless type (RQG) is intended for driving small fans, etc. Drayton Regulator & Instrument Co. Ltd.

EMD 1591 for further information

Hygrometer Alarm

This new hygrometer is said to be so sensitive that it will detect one part of water vapour per million parts of dry air or gas, and to operate under high pressure, temperature or humidity conditions. As the sensing device is in the form of a variable capacitance, contamination does not, it is said, present the difficulties sometimes experienced with hygrometers which use conductive-type elements. It is available in the following versions: indicating, recording, recording and controlling, and adjustable humidity alarm. Shaw Moisture Meters.

EMD 1592 for further information

Limit Switch Device

A range of limit switches is available which give positive indication of the position of the piston in an air cylinder. The mechanism is actuated directly off the shaft of the air piston and operates an electrical microswitch housed in a cylindrical aluminium spinning. The switches can be used as part of an automatic sequence switching system, or to give remote indication of air piston position.

In the photograph, two limit switches are mounted above and below the air cylinder; they are housed in an aluminium casting integral with the air cylinder. Vacuum Research (Cambridge) Ltd.

EMD 1593 for further information

Accelerometer

A new accelerometer, type G88, weighing only 20 gm., has been introduced as a lightweight, high-sensitivity transducer capable of measuring shock and vibration in guided missiles, aircraft, packaging and for general-purpose use. Piezo-electric ceramic material TCL3, which is utilised in the unit, is said to have a wide temperature range from −40 to + 80 deg. C., low-temperature coefficient and long-term stability. This accelerometer is claimed to have a high sensitivity of 80 mV./g. with a capacitance of 1,000 pf., thus enabling measurements to be made down to a few cycles per second when used with a cathode follower of 100 M. output impedance. The transducer is said to have a linear output over the acceleration range of 0·01 to 250 g., a transverse sensitivity of less than 5 per cent in any direction, and individual calibration is made over the range 20-800 c/s. Technical Ceramics Ltd.

EMD 1594 for further information

Miniature Drives

A new series of miniature power drives has recently been developed to perform a variety of functions as clutches, freewheels, backstops or dual drives. As clutches which provide a non-slipping drive, they are said to have numerous applications where power transmission is to be controlled, or a sequence is to be indexed. Control is by means of a pawl which can be operated mechanically, hydraulically, pneumatically or electrically, depending on requirements. As freewheels or backstops, their application is said to be extremely wide, and they can be combined with a clutch if necessary.

The dual drive unit provides two inputs, called primary and secondary. The former drive takes the normal power, but when the power source is stopped the driven member can be rotated in either direction via the secondary drive, without any movement of the power source. This could be used in an application where the power source is off. In spite of their small size (1·03 in. long × 1·5 in. dia.), these clutches are said to transmit 20 lb./in. and, under certain conditions, up to 100 lb./in. Tiltman Langley Ltd.

EMD 1595 for further information

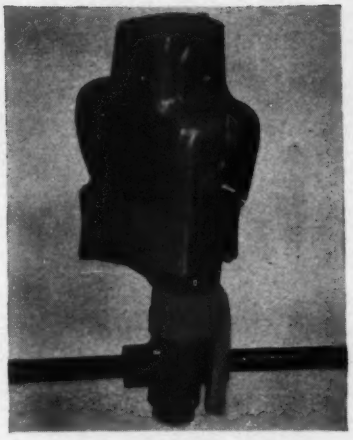
Lightweight Diaphragm Pump

The Mudlite diaphragm is not of the conventional "trapped" type, but is built in the form of a simple, plain, flat neoprene circle, free to move with the stroke of the operating rod and, as a result, is said to be not subject to the stresses of a normal diaphragm. In an emergency, this neoprene circle can temporarily be replaced with a piece cut from ordinary rubber sheeting. The diaphragm acts as its own delivery valve, the only other necessary valve being a simple flap type on the suction side. A sheer key in the large sprocket and safety plates in the diaphragm support provide inexpensive protection in the event of sediment, stones or ice collecting in the bottom chamber. The pump is driven through a reduction gearbox fitted to the engine and a ½-in. cycle chain drive to the eccentric shaft. Auto Diesels Ltd.

EMD 1596 for further information

Rotary Actuator

A new rotary actuator that has become available is designed to turn valves, flaps, cocks and other devices through a right angle and back again in response to an electric signal. It provides an effective substitution of automation for the use of a man's wrist, and it can exert about the same torque. In cases where solenoid



valves are unreliable and of insufficient power, this compact actuator is said to give a strong and positive action, working on the plant air line usually available at 80-100 p.s.i. It will tolerate a temperature of 200 deg. C., the materials will not corrode and a small integral filter prevents ingress of dirt when connecting up. The single rotary-vane piston design gives small overall size, i.e., 3·9 × 4 × 5·5 in. Kinetrol Ltd.

EMD 1597 for further information

Motor Control Unit

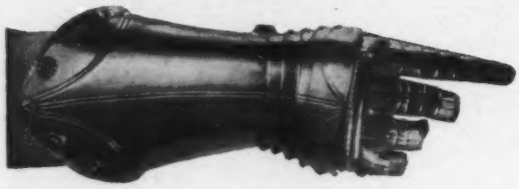
Motor control unit type MCU has been designed to provide means for automatic reversal of electric motors. It can also be used for any other applications where periodic and alternate operation of two electrical circuits is involved, the control unit closes alternately two electrical circuits for continuously adjustable periods at continuously adjustable intervals with the overall timing cycle remaining always constant. The overall timing cycle can be arranged as required—anything from 10 sec. to 30 days. The minimum timed interval which may be pre-set equals approximately 1/60th of the overall timing period. The switching capacity is 6 amp. at 250 or 110 volts a.c. Electrical Remote Control Co. Ltd.

EMD 1598 for further information

Custom-built Pumps

Small air pumps for research and laboratory use are now available in several types. Model D is a pressure pump of the vibrator type, having an inlet through a felt lining between the unit and the case. The outlet is through a control tap and nozzle. Model E is a suction pump of the vibrator type with control tap on the air intake. The pressure pumps can be constructed to give high pressure (about 3 p.s.i.) with low flow or low pressure with high flow (about 4 litres per min.) Suction pumps range from 15 cm. Hg. negative pressure with low flow to low negative pressure at 3 litres per minute. Closed-circuit pumps can also be supplied in sealed form for special gases. All models are custom built to specific requirements, but prototype pumps can be supplied to assist selection. Singleton Bros (Instruments) Ltd.

EMD 1599 for further information



PROTECTION

In days of old, all one had to do to dodge the slings and arrows of outrageous fortune was to throw on a suit of armour and hope for the best.

Now-a-days the technologist takes over and from his 'alchemy' has sprung RALSIN superpolyamide, a safeguard beyond the dreams of ancient armourers, and the boon of modern industry.

Fluidised dip or flame spray any metallic surface with Ralsin and in one operation you have defeated corrosion, imparted a high resistance to abrasion and—since Ralsin comes in a wide range of colours—improved its appearance considerably.

Economically, a Ralsin finish compares very favourably with other nylons, plating, stoving or other protective coatings. It is cheaper than some and better than most.

For a detailed document on the properties of Ralsin, please request Whiffens Publication No. MR/17.

Regd. Trade Mark

RALSIN
fine powder for metal coating from

WHIFFENS

A member of the Fisons Group of Companies

WHIFFEN & SONS LIMITED
WILLOWS WORKS · DERBY ROAD
LOUGHBOROUGH · LEICESTERSHIRE
Telephone: Loughborough 3141.
Telegrams: Whiffen, Loughborough, Telex.
Telex No.: 34548

Whiffen & Sons Ltd. are the sole agents for Ralsin in the United Kingdom, Commonwealth of Australia and the Dominions of New Zealand and Canada.

W42

News of Industry

A new creep test machine designed and produced by the **Electronic and Mechanical Engineering Co. Ltd.** embodies many new features intended to enable test results to be more accurately obtained than is possible by the more conventional equipment. The electrical heating equipment for temperatures up to 1,050 deg. C. is built-in and contains a temperature control system incorporating recorder and automatic cut-out. Autographic creep records can be obtained either directly from the specimen or by recording the movement of the loading lever. Fitted with floating knife edges and self-aligning ball seatings, the bed of the machine measures 3 x 2 ft. By vertical displacement of the furnace, the specimen may be removed without furnace cooling. Capacity of the machine is 1 ton.

Distington Engineering Co. Ltd., a subsidiary of United Steel Cos., have established a new division which will specialise in the design and manufacture of continuous casting plants for both ferrous and non-ferrous metals. Current experimental work by the division includes the production of continuously cast slabs, 36 in. wide and 5 in. thick, and 9 in. square billets. Killed, rimmed and stainless steels have been cast successfully in these sizes, the large slabs having been rolled into plate of excellent quality and the billets into strip of comparable quality.

Thompson L'Hospied & Co. Ltd. have recently incorporated in a tensile machine at their physical testing laboratory an electric furnace fitted with accurate control and temperature recorders. By means of these it is possible to obtain tensile figures for any specific heat-resisting alloy at the temperature at which it will be ultimately used. The figures obtained from this machine, together with those from creep testing machines, can be correlated to provide the designer of, for example, furnace equipment with accurate details to help in selecting a suitable material.

Autosonic inspection equipment has recently been delivered to the Chomutov steel works in Czechoslovakia by **Kelvin & Hughes Ltd.** The equipment is to facilitate the automatic scanning of rolled mild steel bars of up to 7.9 in. dia. and will mark and reject any material containing internal defects in excess of a predetermined degree.

A new international company has been formed jointly by **Head Wrightson & Co. Ltd.** and the U.S. concern, **Arthur G. McGee & Co.** It will have headquarters in London, and will combine the experience of the two parent firms in the design, engineering and building of petroleum refineries and chemical plants through the world outside the U.S.A.

Because of the experience already gained by its structures research department, the **Cement and Concrete Association** is to undertake model testing of concrete structures on a cost basis.

Sutcliffe Hydraulics Ltd. have now moved to new premises at Speedwell Works, Castleford, Yorks.

Agreements covering the production and sale of platinum-titanium electrodes have been signed by **Engelhard Industries Inc.** and **I.C.I. Ltd.** The British company has produced these electrodes for some time; Engelhard will now produce similar ones at their factory in the U.S.A. The two organisations will institute a continuing joint research programme and pool all information acquired.

As part of the Russian current seven-year plan, a **Ukranian Scientific Plastics Research Institute** has been established in Stalino. It will be concerned principally with production problems of synthetic fibres.

The headquarters of the **Firth Cleveland Group** are now at Stornoway House, St. James's, London, S.W.1.

What are claimed to be the largest all-plastics vessels manufactured to date have just been delivered by **Cawley Plastics Ltd.** The vessels, in Tufplas (a chemically-bonded lamination of unplasticised p.v.c. and glass fibre/polyester), are up to 32 ft. high and 4 ft. dia. They have been built for use in a new chemical manufacturing process.

Because of the growing use of a.c. in ships, **English Electric Co. Ltd.** are holding training courses for their customers' engineers in their Liverpool switchgear department.

Marconi's Wireless Telegraph Co. Ltd. and **English Electric Valve Co. Ltd.** have appointed the Ampex Corporation distributors in the U.S.A. of their sound and vision broadcasting equipment and television camera tubes. The agreement includes the sale of the Mk.IV camera which uses either 3 in. or 4½ in. image orthicon camera tubes, the only one of its kind in the world.

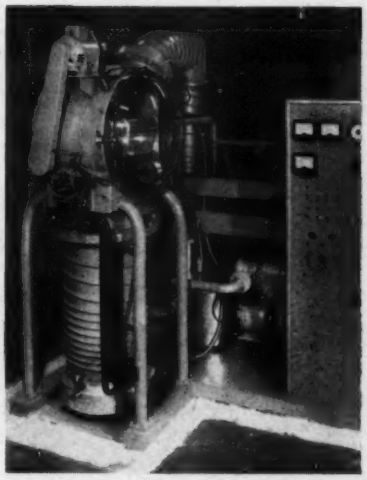
The Institute of Welding has organised a series of four courses on welding technology to take place during September and October.

Streamline Filters Ltd. have moved to new premises at Henley Park, Normandy, Nr. Guildford, the headquarters of the parent company, Vokes Ltd.

A conference on "Polymeric Progress" is being organised by the **Plastics Institute** at London University on March 30-31 next year.

Holman Brothers Ltd. announce the formation of a Spanish manufacturing subsidiary company, Holman Iberica S.A. Production has already started near Madrid of a 120 c.f.m. capacity portable compressor.

The British Standards Institution is considering introducing standards covering the use of new materials for the construction of domestic solid fuel appliances. Firms and organisations which have assembled the results of experience in this field are invited to submit such data for consideration as soon as possible. Letters should be sent to Mr. J. O. Lay, secretary, Technical Committee SFE/13, B.S.I., 2 Park Street, London, W.1.



This new metallic deposition machine made by Vacuum Metallurgical Developments Ltd. produces a metallised finish on paper or plastics that is claimed to be superior in appearance to aluminium foil laminate and at about half cost. With this process, the base material is not dried before treatment.

Air Trainers Link Ltd. have received an order from British Petroleum Ltd. for an electronic analogue computer/process simulator. The computer is based on 0·1 per cent accuracy in all elements; this may often be higher than the accuracy of the input data, but will ensure a range of simulation of not less than four decades.

Research & Control Instruments Ltd. have announced the introduction of the Philips cold box installation—the first of its kind in the world with a net content of about 400 litres for temperatures down to −160 deg. C. Refrigerating capacity at −100 deg. C. is 4,400 B.t.u./hr. and 2,560 B.t.u./hr. at −160 deg. C.

The death has been reported of **Sir Myers Wayman** who (as announced in our last issue) recently became president of the Institution of Engineering Designers.

EMD 1499 for further information

"This is the good brand, Excalibur, or
Cut Steel, and well shall it serve you"

IN FABLE . . . *When King Pellinore shattered King Arthur's sword in combat, the problem of a more worthy weapon was solved by Merlin. . . . "Follow me, and I will bring you where ye shall get you a sword, the wonder of the world".*

IN FACT . . . We do not claim to be magicians, but the problem of coil springs suitable for our hydraulic equipment was solved only when we manufactured our own.

The many military and civil aircraft using our equipment depend as much on our springs as on any other component in that equipment.

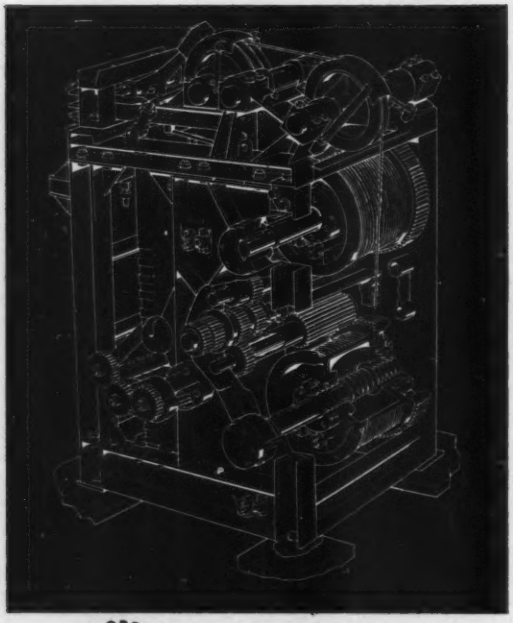
We are proud now to offer to everyone the benefit of our knowledge and experience in manufacturing the correct coil spring for the job . . . springs giving unfailing service . . .

OUR SPRINGS ARE AS DEPENDABLE AS THE EQUIPMENT IN WHICH THEY ARE FITTED

BIRMINGHAM ROAD · WOLVERHAMPTON · ENGLAND · Tel: 24984

INTEGRAL LTD

We design and make MECHANISMS



which are INTRICATE
INGENIOUS
of HIGH ACCURACY
and of GREAT RELIABILITY

We specialise in out-of-the-ordinary mechanisms, such as those for control purposes, which must have qualities of highest precision (no backlash, for instance) and the utmost reliability under all conditions of service.

If you have a special-purpose requirement, for whatever purpose, needing unusual skills in design and extremely competent workmanship, call in John Thompson Ordnance Co. at the commencement and let us see what we can do to take the whole problem off your shoulders.

The illustration is a Chute Winding Gear, part of the mechanism of a 50 ft high machine, controlling a grab which inserts and removes fuel element chutes into and out of the Reactor Pressure Vessel at the Berkeley Nuclear Power Station. The winding gear incorporates many ingenious design features, but above all has to be of extreme reliability, since there must be no possibility of failure.
Manufactured by John Thompson Ordnance Co. to the requirements of A.E.I.—John Thompson Nuclear Energy Co. Ltd.

JOHN THOMPSON GROUP · JOHN THOMPSON ORDNANCE COMPANY

JOHN THOMPSON ORDNANCE COMPANY · WOLVERHAMPTON

OR.4

EMD 1500 for further information